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MINERAL CONTENT OF MANITOBA HAYS[1]

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INTRODUCTION

From time to time reports have been received which indicate that "mineral deficiency" or "malnutrition" of cattle occurs in certain districts in Manitoba. These reports have raised the question whether or not the occurrence of this condition might be due to the mineral composition of the feeds grown in the respective areas. Hence the analysis of hays from various districts was undertaken to obtain information for comparison with hay grown elsewhere; to indicate the districts, if any, where low phosphate hays occur; and to study the effect of the application of fertilizers on the mineral composition of the hay. The initial work already done in this field by the authors has been limited, but, owing to lack of published data on the mineral composition of Manitoba hays, and because of the interest shown in this work, it was considered advisable to submit the information obtained as a contribution to the subject. It is hoped that further information will be added from time to time as work is done in subsequent years.

Relationship of Mineral Deficiency Symptoms and Low Phosphate Content of Feed

The symptoms of malnutrition or mineral deficiency disease as reported in Manitoba cattle include emaciation; depraved appetite (manifested in the chewing of bones, wood, plaster, etc.); enlargement and stiffening of the limb joints; and sometimes spontaneous fractures and easily broken bones. The latter condition is described by Tuff of Norway (*30*) as the most advanced stage of mineral deficiency disease.

The above symptoms are similar to those noted in South Africa, New Zealand, Norway, United States, and many other countries where mineral malnutrition appears to be related to a deficiency of phosphorus in the feed, (or to an incorrect CaO : P_2O_5 ratio). Hart, Beach, DeLwiche and Bailey (*12*) attribute the condition of malnutrition in livestock in Wisconsin to phosphorus deficiency. Theiler, Green and DuToit *(28)* in South Africa; Eckles, Becker and Palmer (*8*) in Minnesota; and others in New Zealand, also link malnutrition with low phosphate intake. Orr (*20*) suggests that phosphorus deficiency is the most important cause of malnutrition in Europe, but Tuff (*30*) believed that the mineral malnutrition reported in Norway is due to a deficiency of both calcium and phosphorus.

[1] This work was carried on in collaboration with the Dominion Experimental Farms in the laboratories of the Soils Division, University of Manitoba.
[2] Soils Division, University of Manitoba.
[3] Dominion Experimental Farms.

Scott (*24*) states that phosphorus deficiency is the chief cause of malnutrition in Montana, but he intimates that limitation of phosphorus may not be the only cause. Huffman (*14*) in Michigan reports a low phosphate content in alfalfa and other hays, coupled with the occurrence of malnutrition. Theiler (*28*) states that the indication of Osteophagis (bone chewing) varies inversely as the amount of P_2O_5 in the pasture produced on the veldt in South Africa. Marcq (*17*) reports that when the P_2O_5 content of grasses in the Belgian Congo is low, Osteophagis develops; and Svanberg (*27*) found that Osteomalacia occurred in cattle in Småland (Sweden), when the animals grazed on moor-land that had a low P_2O_5 content, or when they were fed hay low in phosphate. Thus the relationship of certain forms of malnutrition in cattle, and the low phosphate, or incorrect lime to phosphate ratio of the forage or fodder, appears to be recognized in many countries.

Standard for P_2O_5 in Hays and Pastures

Numerous writers have reported the amount of phosphorus and calcium in hay and pasture which they consider as insufficient to prevent mineral deficiency. A summary of some of these reports is given for reference in Table 1. In this table the column headed "Insufficient" denotes the percentage of P_2O_5 and CaO in hay and pasture which will cause malnutrition according to these writers, whereas the column headed "Sufficient" gives the percentage of P_2O_5 and CaO considered sufficient to prevent mineral malnutrition. The figures given in Table 1 indicate that where mineral deficiency in cattle is reported, the P_2O_5 content of the hay and pasture consumed is low in comparison with the P_2O_5 content of the hays and pasture consumed by animals free from mineral malnutrition.

An exception to this is found in some of the alfalfa hays in Minnesota and Montana. These hays were classified as being from affected districts, but they are higher in phosphate content than the grass hays from areas in which hays are not considered as phosphorus deficient. Huffman (*14*) in Michigan found that alfalfa, having higher values for P_2O_5 than other hays, still produced malnutrition. Meigs (*19*) suggests that in some hays used as feed, the assimilation of phosphate by the animal may be interfered with, due to the higher calcium content of such hays.

Some interesting figures on the phosphate and lime content of palatable and less palatable plants in pastures are given by Godden (*10*) who conducted investigations in the British Isles on the relationship of the mineral content of pastures and the extent to which plants were eaten. His observations are as follows:

		Phosphate and lime content of plants	
		Eaten	Not eaten
English and Welsh Pastures			
	P_2O_5	.516 %	.325 %
	CaO	.464 %	.264 %
Cultivated Grasses			
	P_2O_5	.854 %	.570 %
	CaO	1.186 %	.835 %
The Island of Lewis—			
(Where the nutritive value of herbage is very low.)	P_2O_5	.243 %	.177 %
	CaO	.286 %	.295 %

TABLE 1.—SUMMARY OF ANALYSES OF P_2O_5 AND CaO CONTENT REPORTED FROM VARIOUS SOURCES AS "INSUFFICIENT" AND "SUFFICIENT"

Author	Geographic Location	Crop	Insufficient		Sufficient	
			P_2O_5	CaO	P_2O_5	CaO
			%	%	%	%
Orr (*20*)	Scotland	Pasture	.290	.210		
Stohmann, cited by Eckles, et al (*8*)	Germany	Hay	.210	.630	.430	.900
Kellner, cited by Eckles, et al (*8*)	Germany	Hay	.258	.829	.430	.950
Guthrie, cited by Eckles, et al (*8*)	Australia	Hay	.274	.378	.414	.550
Henry, cited by Orr (*20*)	Australia	Pasture	.278	.382	.560	.415
Tuff (*30*)	Norway	Hay	.150	.360	.440	.880
Dircks, cited by Tuff (*30*)	Norway	Marsh hay	.155	.185		
			.143	.279		
			.129	.287		
Report New Zealand (*21*)	New Zealand	Pasture	.200			
Aston (*5*)	New Zealand	Pasture	.270			
			.190			
			to .260			
Theiler et al (*28*)	South Africa	Pasture	.220		.320–.600	
Hart, et al (*12*)	Wisconsin	Sweet clover hay	.225			
		Alfalfa hay	.328			
Scott (*24*)	Montana	Alfalfa	.284	2.590	.423	2.02
		Clover	.299	2.270	.356	1.47
		Wild grass	.259	.441	.360	.341
Scott (*24*)[1]	Galladin Co. Montana	Alfalfa	.346	2.450	.396	2.08
		Clover	.328	2.300	.336	1.60
		Timothy			.317	.291
		Wild grass	.170	.448		
		Red Top			.333	.370
		Bunch grass hay			.324	.310
Eckles et al (*9*)	Minnesota (Phosphate deficiency area)	Alfalfa	.485			
		Timothy	.242			
		Prairie hay	.256			
Eckles, (*8*)	Minnesota	Alfalfa hay	.434		.588	
		Timothy hay	.245		.310	
		Prairie hay	.229		.248	
Gundy (*7*)	Wyoming	Timothy hay			.329	.277
					to .471	to .394
		Carex hay			.440	.524
					to .459	to .678
		Red Top hay			.344	.253
					to .445	to .365

[1] Average mineral content from hay in years 1926 and 1927.

MANITOBA HAY SAMPLES

In July, 1934, several trips were made throughout the agricultural portion of Manitoba for the purpose of obtaining samples which would give a representative collection of the hays grown during that season. These samples were collected from the Red River Valley, the Inter-Lake area, the West Lake area, the Assiniboine Delta, the Northern Drift, the Southern Drift, the Whitemouth area, and Eastern Manitoba. No samples were obtained from the extreme southwest portion of the province, on account of drought, neither was it found possible for other reasons to obtain samples from the Swan River Valley.

TABLE 2.—AVERAGE PERCENTAGE OF SiO_2 IN MANITOBA HAY SAMPLES. 1934

Kind of hay		Red River	Inter-Lake area	West-Lake area	Assini-boine Delta	Northern Drift	Southern Drift	St. George White-mouth	Eastern	Mean of species
Melilotus alba.	S. clover	.34	.70	.44	.30		.33		.39	.42
Medicago sativa.	Alfalfa		.25					.50		.38
Bromus inermis.	Brome grass	2.83	2.79	3.32	2.01	4.25	5.25		3.09	3.36
Phleum pratense.	Timothy	2.81	2.76					1.82		2.46
Poa spp.	Blue grass	4.22	1.11	1.53		3.82				2.67
Glyceria nervata.	Prairie grass		1.66							1.66
Calamagrostis canadensis	Prairie grass	3.54	2.56						2.58	2.89
Fluminia festucaceae	Prairie grass	4.84	2.63		6.33	4.34				4.24
Sedges, Low land species		3.91	2.98	2.60	3.69	2.54	4.62		1.71	3.15
Legumes		.34	.48	.44	.30		.33	.50	.39	.40
Cultivated grasses		2.82	2.78	3.32	2.01	4.25	5.25	1.82	3.09	3.17
Native grasses		4.20	1.99	1.53	6.33	4.08			2.58	3.45

TABLE 3.—AVERAGE PERCENTAGE OF P_2O_5 IN MANITOBA HAY SAMPLES. 1934

Melilotus alba.	S. clover	.397	.512	.345	.357		.277		.472	.393
Medicago sativa.	Alfalfa		.257					.579		.418
Bromus inermis.	Brome grass	.335	.328	.278	.264	.166	.366		.211	.278
Phleum pratense.	Timothy	.320	.210					.407		.312
Poa spp.	Blue grass	.260	.178	.199		.243				.220
Glyceria nervata.	Prairie grass		.234							.234
Calamagrostis canadensis.	Prairie grass	.222	.208						.248	.226
Fluminia festucaceae	Prairie grass	.230	.208		.221	.194				.213
Sedges. Low land species		.188	.191	.188	.284	.264	.239		.281	.234
Legumes		.397	.384	.345	.357		.277	.579	.472	.401
Cultivated grasses		.328	.269	.278	.264	.166	.366	.407		.297
Native grasses		.238	.207	.199	.221	.218			.248	.222

TABLE 4.—AVERAGE PERCENTAGE OF CaO IN MANITOBA HAY SAMPLES. 1934.

Kind of hay		Red River	Inter-Lake area	West-Lake area	Assini-boine Delta	Northern Drift	Southern Drift	St. George White-mouth	Eastern	Mean of species
Melilotus alba.	S. clover	1.572	1.370	3.042	2.313		1.181		1.361	1.806
Medicago sativa. Alfalfa	Alfalfa		2.677					2.283		2.480
Bromus inermis	Brome grass	.369	.412	.370	.442	.332	.547		.255	.389
Phleum pratense	Timothy	.202	.184					.286		.224
Poa spp.	Blue grass	.280	.396	.445		.286				.352
Glyceria nervata.	Prairie grass		.450							.450
Calamagrostis canadensis.	Prairie grass	.200	.426						.529	.385
Fluminia festucaceae	Prairie grass	.302	.292		.575	.394				.391
Sedges. Low land species		.389	.371	.443	.514	.470	.535		.408	.446
Legumes		1.572	2.024	3.042	2.313		1.181	2.283	1.361	1.968
Cultivated grasses		.286	.298	.370	.442	.332	.547	.286	.255	.352
Native grasses		.261	.391	.445	.575	.340			.529	.423

TABLE 5.—AVERAGE PERCENTAGE OF MgO IN MANITOBA HAY SAMPLES. 1934.

Melilotus alba.	S. clover	1.084	0.531	1.404	0.782		0.728		1.004	0.922
Medicago sativa	Alfalfa		.708					.766		.737
Bromus inermis	Brome grass	.442	.429	.436	.314	.319	.291		.315	.364
Phleum pratense.	Timothy	.283	.323					.265		.290
Poa spp.	Blue grass	.310	.356	.382		.316				.341
Glyceria nervata.	Prairie grass		.508							.508
Calamagrostis canadensis	Prairie grass	.443	.450						.321	.405
Fluminia festucaceae	Prairie grass	.307	.310		.403	.294				.328
Sedges. Low land species		.314	.435	.411	.474	.445	.392		.256	.389
Legumes		1.084	0.620	1.404	0.782		.728	.766	1.004	.913
Cultivated grasses		.362	.376	.436	.314	.319	.291	.265	.315	.335
Native grasses		.353	.401	.382	.403	.305			.321	.361

In general, the weather conditions during 1934 were somewhat drier than usual, and hence the phosphate content of Manitoba hays in that year would tend to be somewhat lower than in normal or wet seasons. On the other hand, it may be pointed out that the samples obtained were cut from the standing crop in the field and stored and dried under ideal conditions in the laboratory; hence it may be expected that hay cured and stacked in the field would have a somewhat lower phosphate content than that found in the samples collected.

The hay samples were cut in July from square yards selected in the field, at the time when the hay crop is cut normally; and, as nearly as possible, they were obtained pure as to variety. The hay samples were dried, ground, and analysed for silica, phosphate, lime and magnesia.

The percentage of silica (SiO_2), phosphate (P_2O_5), lime (CaO), and magnesia (MgO), in the different crops in the various areas are given in Tables 2, 3, 4 and 5 respectively. The figures given represent the averages of all hays of similar species analysed from the respective districts.

DISCUSSION

The results of the 1934 investigation of Manitoba hays indicate that the phosphate content of Manitoba hay is low as compared with hay in some other parts of the world. The average P_2O_5 content of the legumes from all districts was .401%, that of the cultivated grasses was .297%, that of the native grasses .222%, and that of the sedge or swale hays .234%. The P_2O_5 content of the legume hays in all districts, except the Southern Drift area, was higher than in other hays. In the Southern Drift area, however, one sample only of legume hay was collected, and, as it was grown under very dry conditions, it should not be considered as normal for the area. In general, the phosphate content of the native grass and sedge hays were lower than that of the cultivated grass hays. If the P_2O_5 content of the grass hays grown in Manitoba in 1934 is taken as representative, the hay of this province would be classed as "low phosphate hay" according to the standards used elsewhere.

Comparison of P_2O_5 Content of Manitoba Hay and the Animal Requirements

Comparison may be made between the P_2O_5 content of the Manitoba hay samples and the daily requirement of animals. Huffman (*14*) found that a daily intake of 13.0 grams to 22.6 grams of P_2O_5 was not sufficient for the requirements of a calf up to 18 months of age, but that a daily intake of from 22.8 to 27.5 grams was sufficient during the period from birth to the first calving. Theiler (*29*) states that 28 grams P_2O_5 daily is sufficient phosphate for a growing heifer, but Kellner (*15*) gives a daily requirement of 40.6 grams P_2O_5 as necessary for a calf from birth to the age of one year. Riddell (*22*) reports that 34.1 grams of phosphate daily was not sufficient for a milking cow, and that a daily intake of 90.6 grams of P_2O_5 was needed to give a proper phosphorus balance. Eckles et al (*9*) found that one milking cow, receiving 35.4 grams of P_2O_5 daily, and a second cow, receiving 48.6 grams of phosphate daily, began bone chewing within two months. Armsby (*4*) (who drew his conclusions from the work of Henneberg, Stohmann, and Kellner) states that 57.2 grams of P_2O_5 daily is sufficient intake for a cow weighing 1,000 pounds and giving 20 pounds of milk.

If the figures (given by Teheiler) of 28 grams of P_2O_5 are taken as the requirement for a growing heifer, and the figures (given by Armsby) of 57.2 grams of P_2O_5 are taken as the daily requirement for a milking cow giving 20 pounds of milk, then a heifer would have to consume 31 pounds of hay, and a milking cow 63.4 pounds of hay daily, respectively, if fed on native grass hay similar to that obtained from the West-Lake area having an average composition of .199 per cent P_2O_5. As this is considerably in excess of the average daily consumption, it is obvious that the practice of wintering cattle on grass hay alone (which is followed in some parts of Manitoba) is sure to cause phosphorus deficiency in cattle unless sufficient grain or mineral supplement is fed in addition to the hay consumed.

In the Inter-Lake and West Lake areas of Manitoba, the cattle graze on the native grass land during the summer, and during the winter they are fed almost entirely on hay made from the native grass. It is from these two areas that most of the reports of malnutrition come. However, the phosphate content of the grass hays obtained from the other districts was also low, but in these other districts, grain growing is the type of farming generally followed. The reason why mineral malnutrition is not more widespread among cattle in the grain growing districts is due probably to the additional amount of phosphate the cattle obtain from the grain that is fed in sheaf oats or as threshed grain; or from the grain they pick up in the stubble fields or in the straw, etc.

The high phosphorus content of grain is well known. Webster (*31*) reports a P_2O_5 content of .790% in oats, and of .901% P_2O_5 in barley; Berry (*6*) reports that Manitoba oats of the 1912 crop had an ash content of 1.85%, and that the average P_2O_5 content of the oat ash was 52.6%. Sinclair and McElroy (*26*) give a P_2O_5 content of .718% for oats and .726% for barley. Mather (*18*) gives the figure of 1.31% as the P_2O_5 content of barley grown on the wooded soils of Alberta. Henry and Morrison (*15*) give an average figure for P_2O_5 in oat grain of .81%, and in barley of .85%.

Wagner (cited by Alway (*1*)) emphasizes the fact that the P_2O_5 content of cereals shows little variation when grown on mineral soils, but Alway found the P_2O_5 content of cereal grains was increased by the application of phosphate to peat soil. Eckles (*9*) suggests that the phosphorus content of grain does not change to an appreciable extent, but that the composition of the straw may vary considerably. Thus it is logical to assume that cattle on grain farms would obtain a higher phosphorus intake than would the cattle on farms producing little or no grain, even though the grass hay grown had an equally low phosphorus content in both cases.

Lime, Magnesia and Silica Content

The figures obtained for lime, silica and magnesia in the 1934 hay samples are of interest. Throughout the areas studied the CaO and MgO content of legume hays were much higher than in the non-legume hays, but the silica content of the legume hays was lower than that of the grass hays. The average figures for lime, magnesia and silica for all the samples of Manitoba hay obtained in 1934 are as follows:

	Per cent CaO	Per cent MgO	Per cent SiO_2
Legumes	1.968	0.913	0.40
Non-legumes	0.407	0.362	3.23

In all the Manitoba legume hays the lime content exceeds the magnesia content. In the non-legume hays from the Red River and the Inter-Lake areas the magnesia is higher than the lime, but in the other areas the lime is higher than the magnesia in all the non-legume hays with one exception. The soils in the Inter-Lake area have developed on dolomitic parent material or on material containing considerable magnesium. In the Red River Valley, the soils in the low position have a high magnesium salt content, and many of the better drained soils in the Red River Valley contain a large amount of magnesium in the base exchange complex. The relatively high magnesium content of the grass hays in these two areas, therefore, is due probably to the higher amounts of magnesium contained in the soil than is found in the soils in those portions of the province not associated with the dolomitic deposits, and which produce hay with a lower magnesium content.

The differential ratio of lime and magnesia shown in these hay samples may be of further interest by reason of the calcification studies "In vitro" by Shelling, Kramer, and Orent (*25*). These authors state: "experimentally we have found that calcification occurs most rapidly in the absence of magnesium, but the introduction of magnesium . . . . . in excess of the normal concentration, in serum, definitely inhibits the process. The inhibitory effect progressively increases as the magnesium concentration rises . . . . . The inhibitory effect of the magnesium ion can be overcome by suitable increments of inorganic phosphorus."

The authors suggest that the significance of the amounts of CaO, MgO, and P_2O_5, and their ratios in the Manitoba hay samples, and the effect that these hays may have on the development of osteomalacia, would be a worthy subject for investigation by animal nutritionists.

Factors Affecting Composition of Hay

The mineral content of hay depends upon many factors, which include: the composition of the soil; the climatic conditions; the seasonal variation; the plant species; the stage of growth at which the crop is cut; the conditions under which the crop is cured; and, in some cases, the effect of phosphatic fertilizers.

The effect of soil composition on the mineral composition of hay and pastures is generally recognized, but it is important to note that the mineral composition of hays and pastures will vary with seasonal conditions, and that dry weather during the crop growing period results in an aggravation of mineral deficiency symptoms subsequently noticed in cattle.

Tuff (*30*) in Norway reports a severe outbreak of malnutrition in the winter and spring following a drought year. Aston (*5*) in New Zealand, and Theiler (*28*) in South Africa found that malnutrition outbreaks occur during dry periods. Both Kellner and Stohmann (cited by Eckles (*8*)) report outbreaks of Osteomalacia in cattle on areas of impoverished soil or immediately following drought. Eckles (*9*) found that a decrease in rainfall caused a decrease in P_2O_5 content of alfalfa, timothy, and prairie grasses; and that cattle suffer more from phosphorus deficiency during a winter following a summer of low precipitation. Forbes (*11*) states that increased moisture increases the P_2O_5 content of alfalfa and grasses. Chaven (cited by Orr (*20*)) found an increase in P_2O_5 and a decrease in CaO in irrigated meadow-hay in comparison with non-irrigated meadow-hay;

and Lewite in Germany, found that an increase in rainfall resulted in an increase in P_2O_5 content and a decrease in the CaO content of hay.

It appears to be generally accepted that legumes are richer in phosphorus than grasses. This however is not always the case. Orr (*20*) reports rye grass with a higher P_2O_5 content than clover when grown under the same conditions. Similar results were obtained on the University Farm by the writers, when meadow fescue was compared with alfalfa (see table 6). Mather (*18*) found that legumes were higher in P_2O_5 than are prairie grasses. Eckles et al (*9*) have shown that alfalfa hay had a higher P_2O_5 content than prairie hay when grown on the same land in Minnesota. Scott (*24*) reports a higher P_2O_5 content in legumes than in grasses in Montana; Aston in New Zealand (*5*) also found that grasses have a lower P_2O_5 and CaO content than legumes; and Henry and Morrison (*13*) give a summary analyses in which alfalfa and clover are generally higher in P_2O_5 content than grasses.

Analyses were made of the mineral content of different hays grown on the University Farm in the year 1930 and 1931, which show the variation in the mineral composition of different cultivated hay crops when grown on adjacent plots. The different hays sampled include: (1) meadow fescue, (2) brome grass, (3) western rye, (4) timothy, (5) alfalfa and western rye mixture, (6) alfalfa and meadow fescue mixture, (7) alfalfa, meadow fescue, timothy and alsike mixture, and (8) alfalfa.

Duplicate plots of each crop were sampled and a composite sample of each hay species was obtained both in 1930 and again in 1931. The same plots were sampled in each year, so that the resulting data indicate the variation in composition due to season as well as that due to species.

The figures obtained from the analyses for silica-free ash, the silica, the phosphate and lime content are given in Table 6.

TABLE 6.—MINERAL ANALYSES OF HAY SPECIES, UNIVERSITY FARM. 1930–1931

1930		Type of hay	Silica free ash	Silica SiO_2 %	Phosphate P_2O_5 %	Lime CaO %	1930 Ratio CaO : P_2O_5
Grasses	1	Meadow fescue	3.98	4.21	.497	.283	1 : 1.76
	2	Brome grass	2.75	3.50	.272	.132	1 : 2.07
	3	Western rye	2.60	2.86	.304	.186	1 : 1.63
	4	Timothy	2.82	2.51	.318	.151	1 : 2.10
Mixtures	5	Alfalfa and W. rye	3.08	2.80	.321	.700	1 : 0.46
	6	Alfalfa and M. fescue	4.57	3.65	.451	1.165	1 : 0.37
	7	(Alfalfa, M. fescue), (Timothy and alsike)	4.37	2.80	.369	.647	1 : 0.55
Legumes	8	Alfalfa	6.45	0.92	.318	1.880	1 : 0.17

1931		Type of hay	Silica free ash	Silica SiO_2 %	Phosphate P_2O_5 %	Lime CaO %	1931 Ratio CaO : P_2O_5
Grasses	1	Meadow fescue	4.32	6.17	.465	.605	1 : 0.77
	2	Brome grass	3.16	5.68	.288	.339	1 : 0.85
	3	Western rye	1.98	4.81	.231	.414	1 : 0.56
	4	Timothy	2.58	3.04	.293	—	—
Mixtures	5	Alfalfa and W. Rye	5.09	2.14	.228	1.364	1 : 0.17
	6	Alfalfa and M. fescue	5.53	0.88	.298	1.880	1 : 0.16
	7	(Alfalfa, M. fescue), (Timothy and alsike)	5.39	1.40	.206	1.498	1 : 0.14
Legumes	8	Alfalfa	6.38	0.84	.332	1.576	1 : 0.21

The figures in Table 6 are especially interesting due to the fact that the hays from which these figures were obtained were grown on adjacent plots on the same soil type: (i.e., Red River Clay, partly wooded phase). In comparing the data for the grass hays, the relatively high phosphate and silica-free ash contained in the meadow fescue is noteworthy. The hay from the brome grass was low in phosphate in both years. The alfalfa hay in both years was appreciably higher in silica-free ash but not appreciably higher in phosphate than the average of the grass hays. The greatest variation is noticed in the CaO content of the hays in the two years. In 1931 the lime content of the hays increased significantly[1] over that obtained in 1930, but the phosphate content significantly decreased[2].

During the hay growing months of April, May and June in 1930, the total rain-fall was 7.19 inches and the mean temperature for this period was 52.3° F. During the same three months in 1931 there was a rainfall of *3.90 inches* with a mean temperature of 52.7° F. Thus the drier season of 1931 resulted in a markedly higher lime content and a somewhat lower phosphate content with marked change in the lime-phosphate ratio in the hay produced.

The conditions under which hay is cured may affect appreciably the mineral composition of hay. Ames and Blotz (*3*) treated dry alfalfa with water, and found that loss in P_2O_5 and CaO amounted to 75% and 40% respectively. LeClerc and Breazeale (*16*) report that P_2O_5 can be washed from oat and wheat plants when they are mature or near maturity; and that dry grass loses a greater percentage of its P_2O_5 content by washing than does undried grass. Scott (*24*) suggests that the P_2O_5 content in hay is lowered during the process of drying and stacking. The authors found under Manitoba conditions that a sample of sedge or swale hay, which was cut in the Inter-Lake area in September 1934, had a P_2O_5 content of .105%, whereas similar hay cut in that area at the normal time in July of the same year had a P_2O_5 content of .191%.

Thus it is quite evident that the phosphate content of hay is affected by many factors. In addition to variation in composition due to the plant species and the soil on which the plants are grown, changes in relative composition of the ash are affected by seasonal variation, by the stage of maturity at which the crop is cut, and by the conditions under which the crop is cured.

THE EFFECT OF FERTILIZERS ON THE MINERAL COMPOSITION OF HAY

A number of hay samples were collected by the writers at various times from different districts in Manitoba in which fertilizer experiments with hay crops were in progress. The mineral analyses of these hay samples are submitted to indicate the effect of fertilizers on the mineral composition of hay under Manitoba conditions in so far as information is available. The districts from which the fertilized and unfertilized hay samples were obtained include the Inwood district, the Arborg district, the Marchand district and the University Farm, Winnipeg.

Inwood Fertilizer Experiments.—In 1932 hay samples were collected in the Inwood district from non-fertilized native grass hays and from adjacent

[1] The "t" value is 2.565 and the probability greater than .05.
[2] The "t" value is 2.602 and the probability greater than .05.

plots to which 45 pounds per acre of Ammonium Phosphate had been applied broadcast in the spring. The samples were taken from three positions, namely (1) the ridge position, (2) the intermediate position and (3) the swale or low position. The analytical results are given in Table 7.

TABLE 7.—MINERAL ANALYSIS OF HAY FROM INWOOD FERTILIZER PLOTS. 1932

Hay sample from	Treatment	Per cent			Total ash	Silica free ash
		P_2O_5	CaO	SiO_2		
Ridge Position	Fertilized	.286	.417	3.58	5.34	1.76
	Non-fertilized	.121	.285	2.80	4.19	1.39
Transition Phase	Fertilized	.504	.410	4.40	6.80	2.40
	Non-fertilized	.156	.385	5.76	7.56	1.80
Low Swale Phase	Fertilized	.536	.440	2.80	4.91	2.11
	Non-fertilized	.121	.500	5.09	7.29	2.20

The soil in the Inwood district on which the hay was grown is a grassland soil developed on calcareous parent material. The results of the mineral analysis of hay given in Table 7 show that in this experiment the application of phosphate fertilizer resulted in a marked increase in the phosphate content of the hay grown in all three positions, but the increase was greater in the hay grown in the intermediate and low positions than in that grown on the higher land.

Marchand Fertilizer Experiments.—In 1934 hay samples were collected from fertilized and non-fertilized fields on Marchand peat in Eastern Manitoba. The fertilizer used in this experiment was triple super-phosphate applied at the rate of 50 pounds per acre. The results of the mineral analyses are given in Table 8.

TABLE 8.—MINERAL ANALYSIS OF HAY FROM MARCHAND PEAT DISTRICT. 1934

Date of cutting	Species of hay grown	Fertilizer treatment	Per cent			
			SiO_2	P_2O_5	CaO	MgO
July 26	*Phleum pratense* (Timothy)	Triple super-phosphate		.303	.540	.370
July 26	*Phleum pratense* (Timothy)	Check	2.94	.150	.604	.273
July 26	*Phleum pratense* (Timothy)	Triple super-phosphate	2.75	.277	.513	.327
July 26	*Phleum pratense* (Timothy)	Check	1.99	.157	.644	.382
July 26	*Bromus inermis* (Brome grass)	Triple super-phosphate	.97	.246	.545	.364
July 26	*Bromus inermis* (Brome grass)	Check	.99	.202	.451	.279

The figures for phosphate content in Table 8 show an increase in phosphate content both in the timothy and the brome hay grown on the peat soil when treated with phosphate. The phosphate increase was greater in the timothy than in the brome.

Arborg Fertilizer Experiments.—Hay samples were obtained in 1934 from fertilized hay plots at Arborg, Manitoba. The fertilizer was applied by broadcast application in the spring on established grass fields which were being used for the production of hay. Four different plots, each in

duplicate were treated on four different fields as follows:

1. No fertilizer.
2. Triple Super-phosphate — 120 lbs. per acre.
3. Ammonium sulphate — 200 lbs. per acre.
4. Ammonium phosphate (16–20) — 260 lbs. per acre.

The results of the mineral analyses of the hay grown on these plots in 1934 are given in Table 9.

TABLE 9.—MINERAL ANALYSES OF HAY FROM ARBORG FERTILIZER PLOTS. ARBORG, MAN. 1934.

Date of cutting	Species of hay grown	Fertilizer treatment	Per cent			
			SiO_2	P_2O_5	CaO	MgO
July 5	*Bromus inermis* (Brome grass)	Check	2.19	.222	.264	.398
		Phosphate	1.97	.441	.279	.489
		Nitrogen	2.05	.235	.259	.424
		Nitrogen and phosphate	1.68	.395	.227	.453
July 6	*Poa nemoralis* (Blue grass)	Check	4.06	.223	.353	.342
		Phosphate	4.42	.268	.309	.384
		Nitrogen	3.75	.219	.299	.271
		Nitrogen and phosphate	3.90	.427	.371	.323
July 6	Mixed *Poa* Spp. (Blue grass)	Check	2.35	.262	.291	.271
		Phosphate	2.77	.309	.348	.371
		Nitrogen	2.26	.253	.406	.407
		Nitrogen and phosphate	1.73	.460	.391	.392
July 6	*Phleum pratense* (Timothy)	Check	2.53	.298	.166	.305
		Phosphate	2.52	.339	.172	.310
		Nitrogen	1.86	.302	.186	.336
		Nitrogen and phosphate	2.08	.505	.192	.344

The analytical data in Table 9 show an increase in the phosphate content of the hay in all cases where phosphate fertilizers were applied both on the peat and on the mineral soils in the Arborg districts.

The Inwood and Arborg experiments are located in the Inter-Lake area, and the Marchand experiments are located in Eastern Manitoba, and in all these experiments increase of the phosphate content of the hay followed as a result of the application of phosphate fertilizer both on the peat and on the mineral soils.

University Farm Fertilizer Experiments.—A more elaborate fertilizer experiment with hay on the University Farm, Winnipeg, (sampled for hay analyses in 1931 and 1932) did not show the marked difference in the phosphate content of the hay as a result of the application of phosphatic fertilizers as did the Inwood, Arborg and Marchand experiments. The soil of the University Farm, Winnipeg, on which the fertilizer experiments were conducted, is a black-earth soil, of clay texture, which for some years prior to cultivation had undergone woodland invasion.

The crop which was grown on the hay plots was a mixture of meadow fescue, timothy, alfalfa and alsike, grown in a rotation of: first year, seed down; second year, hay; third year, hay; fourth year, corn. This experiment has been underway since 1919. Commercial fertilizers were applied

in the spring of the first year, immediately prior to seeding, and barnyard manure was applied also at various times as outlined in Table 10. The hay samples were obtained for analysis in 1930 from seventeen plots in Block B, Range 30, which represented the second year after seeding (or the third rotation year), and from seventeen plots in Block B, Range 33, which represents the first year after seeding (or the second rotation year). The seventeen plots in Block B, Range 33, were also sampled in 1931, which represented the second year after seeding (or the third rotation year). The mineral analyses for the hay grown in 1930 are given in Table 10 and 11, and the analyses of the hay grown in 1931 are given in Table 12.

TABLE 10.—MINERAL ANALYSES OF HAY FROM FERTILIZER EXPERIMENT. UNIVERSITY FARM, WINNIPEG.
Block B, Range 30 (Plots 1–17). 1930

Plot No.	Treatment	Silica free ash	Silica SiO_2 %	Phosphate P_2O_5 %	Lime CaO %
1	Check	4.22	2.21	.254	.974
2	Phosphate (600 lbs. Super)	4.30	2.30	.282	.897
3	Potash (200 lbs. Muriate)	3.40	2.59	.341	.780
4	Nitrogen (320 lbs. Sodium Nitrate)	3.53	2.32	.309	.783
5	Lime (2000 lbs. hydrated)	3.88	2.16	.284	.973
6	Liquid manure	3.49	2.74	.270	.645
7	Check	3.33	2.34	.279	.608
8	Nitrogen, Phosphate, Potash	4.21	2.77	.330	.799
9	Nitrogen, Phosphate	4.27	2.32	.311	1.147
10	Nitrogen, Potash	3.81	2.56	.270	.780
11	Phosphate, Potash	4.06	2.34	.245	.990
12	Check	3.35	2.48	.300	.895
13	Manure* spring, Year 4	4.16	2.37	.348	1.037
14	Manure, before seeding, Year 1	2.89	2.15	.282	.875
15	Manure, grass up, Year 1	3.24	2.16	.364	.990
16	Fresh manure, 1st winter after seeding	3.91	1.92	.380	1.378
17	Rotted manure after hay cut, Year 2	3.40	1.89	.343	1.110

* Barnyard manure, when applied, at the rate of 10 ton per acre.

TABLE 11.—MINERAL ANALYSES OF HAY FROM FERTILIZER EXPERIMENT. UNIVERSITY FARM, WINNIPEG.
Block B, Range 33 (Plots 1–17). 1930

Plot No.	Treatment	Silica free ash	Silica SiO_2 %	Phosphate P_2O_5 %	Lime CaO %
1	Check	3.42	3.16	.229	.857
2	Phosphate (600 lbs. Super)	4.31	2.60	.369	.931
3	Potash (200 lbs. Muriate)	3.77	2.61	.234	.818
4	Nitrogen (320 lbs. Sodium Nitrate)	3.60	1.82	.252	.685
5	Lime (2000 lbs. Hydrated lime)	3.80	2.24	.291	.665
6	Liquid manure	3.64	2.58	.337	.627
7	Check	3.83	2.75	.286	.839
8	Nitrogen, Phosphate, Potash	3.94	1.84	.270	.725
9	Nitrogen, Phosphate	—	2.73	.353	.724
10	Nitrogen, Potash	2.78	2.42	.341	.799
11	Phosphate, Potash	3.47	2.62	.366	.949
12	Check	2.97	2.46	.330	.816
13	Manure,* Spring, Year 4	3.05	2.62	.279	.742
14	Manure, before seeding, Year 1	3.55	2.59	.332	.949
15	Manure, grass up, Year 1	3.17	2.75	.314	.742
16	Fresh manure, 1st winter after sowing	3.73	3.28	.398	.644
17	Rotted manure, after hay cut, Year 2	4.08	2.63	.325	.840

TABLE 12.—MINERAL ANALYSES OF HAY FROM FERTILIZER EXPERIMENT. UNIVERSITY FARM, WINNIPEG.

Block B, Range 33 (Plots 1–17). 1931.

Plot No.	Treatment	Silica free ash	Silica SiO_2 %	Phosphate P_2O_5 %	Lime CaO %
1	Check	5.05	1.59	.353	1.700
2	Phosphate (600 lbs. Super)	4.59	2.06	.318	1.184
3	Potash (200 lbs. Muriate)	4.25	2.48	.277	1.191
4	Nitrogen (320 lbs. Sodium Nitrate)	4.34	1.86	.261	.991
5	Lime (2000 lbs. Hydrated lime)	4.69	1.93	.284	1.389
6	Liquid manure	3.95	2.04	.266	1.110
7	Check	5.16	1.93	.261	1.490
8	Nitrogen, Phosphate, Potash	4.92	1.21	.252	1.011
9	Nitrogen, Phosphate	4.53	1.74	.275	1.144
10	Nitrogen, Potash	4.54	1.44	.272	1.456
11	Phosphate, Potash	4.53	1.51	.332	1.201
12	Check	4.48	1.43	.339	1.317
13	Manure,* Spring, Year 4	4.57	1.56	.307	1.432
14	Manure, before seeding, Year 1	4.51	1.70	.316	1.092
15	Manure, grass up, Year 1	5.18	1.54	.357	1.261
16	Fresh manure, 1st winter after sowing	4.05	2.22	.330	1.131
17	Rotted manure, after hay cut, Year 2	4.45	1.91	.311	1.151

* Barnyard manure, when applied, at the rate of 10 ton per acre.

Owing to the fact that these analyses deal with hay mixtures instead of with single species the results obtained may be open to considerable criticism, and there may be some doubt as to whether this material is suitable for analytical studies. Field inspection before harvesting, however, revealed a very uniform stand throughout both blocks in 1930, and the block sampled in 1931 as (B.33), was the same block as (B.33) sampled in 1930.

The most striking difference in the analyses given in Tables 10, 11 and 12 is the higher CaO content of the hay from Block B, Range 33, in 1931 over that of the hay from the same block but grown in 1930. This increase in CaO is significant.[1] The results given in Table 10 and 11 of the lime analysis of the hay sampled in the same year (namely 1930) show that the mean CaO content of the hay grown in Block B, Range 30 is higher than in Block B, Range 33.[2]

If the figures for lime in the hay of the third rotation year, grown on (B.30) in 1930 are compared with the lime content of the hay grown on (B.33) in 1931 a significant increase is apparent.[3] As there is a significant decrease in silica in the hay grown in 1931 in comparison with that grown in 1930, it would indicate that the percentage of legumes in the hay mixture was higher in 1931 than in 1930, and it is therefore probable that the calcium content increase in 1931 is due in part to a change in species composition.

If the plots receiving phosphate alone or in combination are compared with the comparable plots receiving no phosphate, and the potash plots are

[1] "t" value = 9.7104 "P" greater than 0.01.
[2] "t" value = 2.6020 "P" greater than 0.02.
[3] "t" value = 0.9271 "P" greater than 0.01.

not included, there appears to be only a slight tendency for increase in P_2O_5 content of the hay. When the plots which received potash in addition are considered, this slight tendency to increase in the P_2O_5 content of the hay is not apparent on the plots receiving applications of mineral phosphate. Statistically (with the use of the variance method) there is no significant increase in the phosphate content of the hay grown in this experiment on the plots fertilized with mineral phosphate. If plots 14, 15 and 16 (to which barnyard manure was applied) are compared with the checks there is a slight but significant increase in P_2O_5 content of the hays from the plots which received barnyard manure.[1]

It may be pointed out that in the Inwood, Marchand and Arborg experiments the plots treated with phosphate all showed an increase in the yields of the hay. The increase in most cases was very marked and in all these cases the phosphate content of the hays was increased by the application of phosphatic fertilizers. In the hay plots on the University Farm, Winnipeg, which are reported above, there has been no marked increase of yield in the hay with the application of phosphate, and the application of phosphate gave little or no increase in the phosphate content of the hay. Thus it would appear that where the soil has a phosphate deficiency and response in the yield of hay is secured from the application of phosphate, an increase in the phosphate content of the hay may be expected from the application of phosphatic fertilizers. On the other hand, where the soils are not deficient in phosphate and an increase in yield is not obtained from the application of phosphatic fertilizers, any change in the phosphate content of the hay as a result of fertilizer application, is doubtful.

SUMMARY

1. "Mineral deficiency" or "malnutrition" in cattle has been reported as occurring in several districts in Manitoba. The symptoms are similar to the "mineral malnutrition" symptoms reported in other countries, in which malnutrition diseases occur, due to low phosphate content in the hay and pasture.

2. A preliminary investigation of the mineral content of Manitoba hay was made in 1934. The data obtained (which are considered as preliminary only) may be summarized tentatively as follows:

(a) Swale grass (or sedge) hays grown in Manitoba in 1934 were generally lower in phosphate than native upland grass hays, and the latter were generally lower in P_2O_5 content than the cultivated grass hays. Alfalfa and sweet clover hays generally, but not always, were higher in P_2O_5 content than non-legume hay, but they were invariably higher in their CaO content and much lower in silica.

(b) All the native low-land grass hays grown in Manitoba in 1934 and many of the cultivated grass hays, would be classed as low or tending towards the low order in respect to P_2O_5 content, if they are measured by the standards used elsewhere. Cattle wintered exclusively on these hays could not eat sufficient hay to maintain a proper phosphorus balance, and such hays used as feed for cattle would require to be balanced for phosphorus, and CaO : P_2O_5 ratio, as well as for digestible nutrients and protein.

[1] "z" value = .9271. 5% point = .7630.

(c) The data available indicate that the low phosphate hays are not confined to any one district, but that they are distributed over the area sampled. Hence it would be logical to assume that the reason why mineral malnutrition is not more widely distributed in Manitoba is that the cattle kept on grain farms receive a higher phosphate intake from sheaf oats, or from grain (fed either as supplementary feed or picked up by the cattle from the stubble, straw, etc.).

3. The mineral content of hays depends upon the soil; the plant species; the climate and seasonal variations; the stage of maturity at which the crop is cut; the conditions under which the crop is cured; and in some cases, the fertilizer treatment.

(a) The cultivated hay crops grown on the University Farm, 1930 and 1931, showed considerable variation in mineral composition due to plant species. Alfalfa had the highest silica free ash, the highest CaO content, and the lowest SiO_2 content; but it was not higher in P_2O_5 than the average of the grass hays. Meadow fescue hay had the highest CaO content and silica free ash of all the grass hays, and a higher P_2O_5 content than all other hays, including alfalfa, when grown on the same soil in two successive seasons.

(b) The hay crops grown on the University Farm in two successive seasons showed a marked variation in CaO : P_2O_5 ratio due to the marked increase in CaO content of the hays grown in the drier season.

(c) The indications are that the late cutting of hay after the normal time lowers the phosphate content.

(d) In the curing process soluble minerals, including phosphate, may be washed out of the hay. Hence the method of curing hay should be given careful attention.

(e) The application of phosphatic fertilizers to mineral soils in the Inwood district, to mineral and peat soils in the Arborg district, and to peat soil in the Marchand district, resulted in an increase in the phosphate content of the phosphate fertilized hay crops over that contained in the crops grown on the unfertilized plots. The application of mineral phosphate fertilizers to the soil on the University farm did not show a singificant increase in the phosphate content of hay grown on the treated plots, but a significant increase in the phosphate content of the hay was obtained on the plots which were manured with barnyard manure. It is suggested that the phosphate content of hay may be increased by the application of phosphatic fertilizers, if the phosphate in the soil is either low in quantity or not readily available; but, that the application of phosphate fertilizers to soil may not result in an increased phosphate content of the hay if normal crop yields are produced without fertilizer treatment.

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BIBLIOGRAPHY

1. Alway, F. J., Shaw, W. M., and Methley, W. J. Phosphoric acid content of crops grown upon peat soils as an index to the fertilization received or required. Jour. of Agr. Res., *33* : 701. 1926.
2. Analytical Methods of the Official Agricultural Chemists Association. 1925 Edition. p 2, sec. 6.
3. Ames, J. W., and Blotz, G. E. Nitrogen and mineral constituents of the alfalfa plant. Ohio Agr. Exp. Sta. Bull. No. 247. 1912.
4. Armsby, H. P. The Nutrition of Farm Animals. McMillan Company, New York. 1917.
5. Aston, B. C. Mineral content of pastures. New Zealand Jour. of Agr. *37* : 242. 1928.
6. Berry, R. A. Composition of oat grain and straw. Jour. of Agr. Sci. 10 : 359. 1920.
7. Cundy, A. T. Wyoming forage plants and their chemical composition No. 6. Wyoming Agr. Exp. Sta. Bull. No. 146. 1924.
8. Eckles, C. H., Becker, R. B., and Palmer, L. S. A mineral deficiency in the ration of cattle. Minnesota Agr. Exp. Sta. Bull. No. 229. 1926.
9. Eckles, C. H., Gullickson, T. W., and Palmer, L. S. Phosphorus deficiency in the rations of cattle. Minnesota Agr. Exp. Sta. Bull. No. 91. 1932.
10. Elliott, W., Orr, J. B., Wood, T. B., and Godden, W. Investigation on the mineral content of pasture grass and its effect on herbivora. Jour. of Agr. Sci., *16* : 78.
11. Forbes, E. B., Whittier, A. C., and Collision, R. C. The mineral nutrients in blue grass. Ohio Agr. Exp. Sta. Bull. No. 222. 1910.
12. Hart, E. B., Beach, B. A., Delwiche, E. J., and Bailey, E. G. Phosphorus Deficiency and a dairy cattle disease. Wisconsin Agr. Exp. Sta. Bull. No. 389. 1927.
13. Henry, W. A., and Morrison, F. B. Feeds and Feeding, Table III. Appendix. R. R. Donnelly and Sons, Chicago. 1915.
14. Huffman, C. E., Robinson, C. S., Duncan, C. W., Lamb, L. W., and Mason, M. F. A study of the phosphorus requirements of dairy cattle. Jour. of Dairy Sci., *16* : 203. 1933.
15. Kellner, O. Scientific feeding of animals. Translation by William Goodwin. The McMillan Co., New York. 1910.
16. LeClerc, J. A., and Breazeale, J. F. Plant food removed from growing plants by rain or dew. Year book of the U.S.A. Dept. of Agric. 1908, p. 389.
17. Marcq, J. Nutritive value of phosphorus in Cattle feeding. Int. Rev. Sci. Practice, Agric. *3* : p. 58. 1925.
18. Mather, T. H. The effect of fertilizers upon the forms of phosphorus and the amounts of phosphorus, nitrogen and silica in hays. Sci. Agr. *10* : p. 35. 1929.
19. Meigs, E. B., Turner, W. A., Harding, T. S., Hartmann, A. M., and Grant, F. M. Calcium and phosphorus metabolism in dairy cows. Jour. of Agr. Res. *32* : p. 833. 1926.
20. Orr, J. B. Composition of pastures. Empire Marketing Board Bull. No. 18. 1929.
21. Report of the New Zealand Dept. of Scientific and Industrial Research. p. 24. 1931.
22. Riddell, W. H., Hughes, J. S., and Fitch, J. B. The relation of phosphorus deficiency to the utilization of feed in dairy cattle. Kansas Agric. Expt. Stat. Bull. No. 36. 1934.
23. Ross, Wm. H. The volumetric determination of phosphoric acid. Jour. of Off. Agr. Chemists; *13* : p. 203. 1930.
24. Scott, S. G. Phosphorus deficiency in forage feeds of range cattle. Jour. of Agr. Res. *38* : p. 113.
25. Shelling, D. H., Kramer, B., and Orent, E. R. Jour. of Biol. Chem. *77* : p. 157. 1928.
26. Sinclair, R. D., and McElroy, L. W. The addition of protein and calcium to a ration of small grains for growing pigs. Sci. Agr., *15* : p. 445. 1935.
27. Svanberg, O. Phosphorus deficiency diseases of cattle in Småland, (Sweden). Kgl. Landtbrucks-Akad. Handl. Tids. 71-41. (Chem. Abs. *26* : p. 4360). 1932.
28. Theiler, Sir A., Green, H. H., and DuToit, P. J. Phosphorus in the livestock industry. Jour. of the Dept. of Agr. South Africa, *8* : p. 460. 1924.
29. ———————————————. Minimum mineral requirement in cattle. Jour. of Agr. Sci. *17* : p. 291. 1927.
30. Tuff, Dr. Osteomalacia and its occurrence in cattle in Norway. Proc. of the World's Dairy Congr. *2* : p. 1494. 1923.
31. Webster, J. E. Phosphorus distribution in grains. Jour. of Agr. Sci., *37* : p. 123.

THE EFFECT OF A SPRING FROST ON YIELDS OF SPRING SOWN GRAIN[1]

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INTRODUCTION

It is desirable to know as much as possible about the nature and extent of injury suffered by crop plants as a result of natural agencies such as unfavorable weather conditions and crop pests. Often information of this kind proves its value very promptly by enabling the agriculturist to guard against the loss resulting from such injuries. Until, however, he is aware that definite loss may be sustained the agriculturist is unlikely to take action. Where the loss is connected almost directly with the cause, as in the case of hail damage just before harvest, the problem is relatively simple. Frequently, however, the economic loss resulting from a given cause is far removed in time from the cause, and the connection between cause and effect is obscure.

For example, a spring frost may cause obvious damage to spring sown wheat but the effects on height, earliness and yield are generally unknown owing to the fact that these characters are not seen until about two months after the easily observable effects of the frost have disappeared. Furthermore, there are usually many other factors which affect the characters under consideration and there is no comparable non-frosted material against which to measure the injured material.

As a rule, a carefully planned test under controlled conditions is necessary in order to obtain information of value in a case of this sort. Sometimes, however, Nature furnishes a test in which controls are provided through the genetic differences within the materials. Such a test took place recently at Saskatoon, in Western Canada.

On the night of June 4, 1935, a general frost occurred at Saskatoon and injured most of the crops of cereals and flax which at that time were in the two- and three-leaf seedling stage. Peltier and Kiesselbach (*4*) found in their controlled refrigeration experiments that cereal seedlings were materially more susceptible to frost injury in the two- and three-leaf stage of growth than at earlier or later stages. As has been shown by the writer (*1*) there were pronounced differences in the amount of injury suffered by different varieties of the various crops as a result of this frost. It was particularly interesting however that within nearly every variety there was a range from apparently wholly uninjured seedlings to those which were injured more or less severely. In many cases uninjured plants were found to be within a few inches of plants which had suffered greatly. No observable environmental cause was found to account for a large proportion of the differences. Possibly many of the differences may prove

[1] Contribution from the University of Saskatchewan.

[2] Professor of Field Husbandry. The writer is indebted to Mr. W. H. Horner, graduate assistant in cereals, who took the frost notes and yields.

to be genetic. Whether or not that may be the case it appeared obvious that the plants which had suffered severely would have at least a temporary set back and probably be handicapped in comparison with plants which showed no injury.

Waldron (*6*) studied wheat plants after they had been injured by severe April and May frosts under natural nursery conditions. The frosted plants suffered reductions in yield which did not appear to be compensated for by the yields of adjacent non-injured plants. He found that varieties differed markedly in the amount of loss sustained. In one case he calculated that Hope wheat had suffered a loss of 37% of its potential yielding capacity.

Ivanov (*2*, *3*) recently reported the results of controlled refrigeration experiments on the response of spring crops to spring frost. He found that severe spring frost lowered yields of small grains considerably but some varieties showed more reduction in yield than others of the same crop. Visible injury was not always correlated with reduction in yield; for example, a hemp variety which showed no visible injury at −8° C. suffered a yield reduction of 47.5%. His results showed actual yield increases of 12.5% and 23.5% for oats at −3° C. and barley at −5° C., respectively, but exposure to more severe freezing temperatures depressed the yields far below those of the checks.

Rzhavitin (*5*), working on flax in the late seedling stage under controlled refrigeration conditions, found that varieties differed distinctly in resistance to low temperatures. Most of the varieties suffered injury at −4.5° to −5° C. and were killed at −5.5° to −6° C. The frost injury resulted in weakened growth, delayed flowering, less height and reduced yields of stems and seeds. Varieties from southern countries suffered most while some northern varieties appeared to recover completely.

In the present case the early June frost at Saskatoon presented an excellent opportunity for obtaining information on the effect of seedling frost damage on grain yield in wheat, oats, barley and flax.

MATERIALS AND METHODS

Three days after the frost a large number of plants showing frost injury and an equal number showing no frost injury were marked in each of several varieties in a series of fortieth acre plots. This was done by searching until an uninjured plant and a badly injured one of like age were found to be growing within a few inches of each other with no protecting clod of earth or other apparent reason for the difference in injury. The injured seedling was then marked with a black peg and the uninjured one with a white peg. The procedure was continued until pairs of plants had been marked as follows: 58 pairs in Colsess barley (C.A.N. 772), 27 in Marquis wheat (C.A.N. 1404), 23 in Gopher oats (C.A.N. 14), 35 in Bison flax (C.A.N. 2100), 35 in Crown flax (C.A.N. 2109) and 42 in W.R. 28 flax (C.A.N. 2266).[3] In the case of the cereals no plants were so badly injured that they died as a result of the frost injury, but in the flax varieties (notably Crown) a large proportion of the frosted seedlings did not survive.

[3] The origins of these varieties are given in literature citation *1*.

The injured seedlings were not equally injured but lack of time prevented a separate record being made of the amount of apparent injury suffered by each plant. However, on the basis of a scale of 0 to 10 where 0 indicates complete killing of above ground parts and 10 indicates no apparent damage, the plants pegged as injured ranged between 3 and 5, inclusive.

The yield of plants injured by spring frost presumably depends to some extent upon the weather conditions prior to and subsequent to the frost. In Table 1 a record of temperature, wind velocity, humidity, sunshine and precipitation is given for the eight-day period centering on the occurrence of the frost. The temperature record was obtained from a thermograph[4] located 1,200 feet from the cereal nurseries. The other data were obtained from the University meteorological station.

TABLE 1.—WEATHER CONDITIONS AT SASKATOON DURING THE PERIOD IMMEDIATELY PRECEDING AND FOLLOWING THE FROST OF JUNE 4, 1935

	Day in June							
	1	2	3	4	5	6	7	8
Temperature in degrees Fahr.								
At 2 a.m.	44.0	51.0	43.0	32.0	42.0	44.0	35.0	47.0
At 2 p.m.	70.0	59.0	51.0	55.0	55.0	61.0	67.0	73.0
Average	58.0	52.0	46.0	41.0	48.0	52.0	54.0	62.0
Humidity in %								
Average 8 a.m. to 8 p.m.	43.0	57.0	48.0	45.0	41.0	48.0	26.0	32.0
Average 8 p.m. to 8 a.m.	73.0	72.0	78.0	85.0	80.0	84.0	58.0	64.0
Sunshine								
Total hours	2.5	6.1	6.7	5.2	4.5	9.8	13.9	10.1
Wind velocity								
Average miles per hour	10.7	23.3	20.1	7.5	13.7	7.3	6.4	17.8
Precipitation in inches	0.03	0.02	0.00	0.20	0.01	0.03	0.00	0.00

	Hour on June 4							
	12 p.m.	1 a.m.	2 a.m.	3 a.m.	4 a.m.	5 a.m.	6 a.m.	7 a.m.
Temperature in degrees Fahr.	38.0	36.0	32.0	27.0	28.0	36.0	36.0	40.0
Humidity in %	74.0	76.0	81.0	91.0	95.0	92.0	80.0	63.0

The weather both before and after the frost was ideal for the growth of cereal crops. Between 1 a.m. and 2 a.m. on the night of the frost the temperature dropped to 32° Fahr., at 3 a.m. it was 27°, at 4 a.m. 28° and by 5 a.m. it had risen to 36°. The thermograph was located four feet above the ground surface at approximately the same elevation as the breeding nurseries.

RESULTS FROM PAIRED PLANTS

Colsess Barley

Fifty-two of the 58 pairs of plants staked in Colsess barley produced data. In the case of the other six pairs one or other of the plants in each pair failed to produce seed on account of smut. Table 2 gives the grain

[4] Operated by the Dominion Entomological Branch.

yields of each plant of the 52 pairs. In only 6 of the 52 comparisons did the frost-injured plant show the higher yield. The average yield of the frosted plants was 1.75 gm. whereas that of the non-frosted plants was 3.58 gm. or 105% more. A variance analysis of the results showed that the difference is highly significant.

TABLE 2.—INDIVIDUAL GRAIN YIELDS (IN GRAMS) OF COLSESS BARLEY PLANTS SEVERELY INJURED BY A SPRING FROST COMPARED WITH THE YIELDS OF ADJACENT PLANTS OF THE SAME VARIETY WHICH WERE APPARENTLY NOT INJURED BY THE FROST

Plant pair number	Frosted	Non-frosted	Diff. favor non-frosted	Plant pair number	Frosted	Non-frosted	Diff. favor non-frosted
1	2.70	7.90	5.20	26	0.80	4.60	3.80
2	2.90	4.00	1.10	27	2.85	6.30	3.45
3	1.90	3.30	1.40	28	0.90	3.00	2.10
4	1.60	3.35	1.75	29	3.45	3.20	−0.25
5	2.00	4.90	2.90	30	1.30	3.15	1.85
6	0.25	4.35	4.10	31	0.60	4.20	3.60
7	2.55	1.90	−0.65	32	1.30	2.10	0.80
8	1.20	6.45	5.25	33	1.30	3.20	1.90
9	0.95	3.45	2.50	34	0.40	4.50	4.10
10	1.40	2.40	1.00	35	1.80	4.10	2.30
11	1.80	3.15	1.35	36	2.20	3.10	0.90
12	0.80	3.10	2.30	37	2.30	3.95	1.65
13	2.10	2.00	−0.10	38	1.60	5.30	3.70
14	3.50	1.80	−1.70	39	6.00	6.20	0.20
15	1.70	3.55	1.85	40	0.80	3.55	2.75
16	1.25	2.20	0.95	41	1.50	2.60	1.10
17	2.05	2.30	0.25	42	1.50	3.05	1.55
18	1.95	2.90	0.95	43	0.30	2.10	1.80
19	1.15	4.70	3.55	44	0.80	3.50	2.70
20	1.20	2.75	1.55	45	2.40	2.00	−0.40
21	0.90	3.35	2.45	46	1.20	4.15	2.95
22	3.75	7.85	4.10	47	1.20	2.30	1.10
23	3.15	2.05	−1.10	48	1.80	2.30	0.50
24	1.40	2.00	0.60	49	1.30	2.75	1.45
25	1.30	4.65	3.35	50	1.05	4.30	3.25
				51	2.20	4.30	2.10
				52	2.20	2.25	0.05
				Average	1.75	3.58	1.83

F=56.7. 1% point=6.90.

Marquis Wheat

A total of 27 pairs of plants were staked in Marquis wheat. The data on yields are given in Table 3. In 8 of the 27 comparisons the frosted plant outyielded the comparable non-frosted plant. The difference between 86 gms., the average yield of the frosted plants, and 99 gms., the average yield of the non-frosted plants amounted to 12% in favor of the non-frosted plants and is not significant statistically. This difference is very small compared to that which was found in Colsess.

TABLE 3.—INDIVIDUAL GRAIN YIELDS (IN GRAMS) OF MARQUIS WHEAT PLANTS SEVERELY INJURED BY THE FROST OF JUNE 4TH, COMPARED WITH THE YIELDS OF ADJACENT UNINJURED PLANTS OF THE SAME VARIETY

Plant pair number	Frosted	Non-frosted	Diff. favor non-frosted	Plant pair number	Frosted	Non-frosted	Diff. favor non-frosted
1	0.45	1.65	1.20	16	0.40	1.20	0.80
2	1.80	1.00	−0.80	17	0.80	1.25	0.45
3	1.20	1.60	0.40	18	0.35	0.40	0.05
4	0.60	1.00	0.40	19	0.30	0.90	0.60
5	0.70	0.80	0.10	20	0.45	0.50	0.05
6	0.70	1.15	0.45	21	1.60	0.70	−0.90
7	0.70	0.65	−0.05	22	1.85	0.90	−0.95
8	1.10	1.00	−0.10	23	0.90	0.75	−0.15
9	0.25	1.00	0.75	24	0.80	0.80	0.00
10	1.00	1.10	0.00	25	1.30	1.90	0.60
11	0.70	0.95	0.25	26	0.85	1.25	0.40
12	1.10	0.65	−0.45	27	1.25	1.30	0.05
13	0.75	0.90	0.15				
14	0.35	1.00	0.65	Average	0.86	0.99	0.13
15	1.10	0.50	−0.60				

F=1.38. 5% point=4.0. 1% point=7.2.

Gopher Oats

The data on 23 pairs of plants of Gopher oats are given in Table 4. In 6 of the 23 cases the frosted plant outyielded the non-frosted one. The average yield of the frosted plants was .59 gms., and the average for the non-frosted plants was .72 gms. The difference in favor of the non-frosted plants is 22%, but is not statistically significant.

TABLE 4.—INDIVIDUAL GRAIN YIELDS (IN GRAMS) OF GOPHER OAT PLANTS SEVERELY INJURED BY THE FROST OF JUNE 4TH COMPARED WITH THE YIELDS OF ADJACENT PLANTS OF THE SAME VARIETY

Plant pair number	Frosted	Non-frosted	Diff. favor non-frosted	Plant pair number	Frosted	Non-frosted	Diff. favor non-frosted
1	0.20	1.00	0.80	16	0.95	0.50	−0.45
2	0.50	0.70	0.20	17	0.60	1.00	0.40
3	1.00	1.25	0.25	18	0.60	0.70	0.10
4	0.55	0.70	0.15	19	0.90	0.70	−0.20
5	0.60	0.40	−0.20	20	0.65	0.70	0.05
6	0.50	0.50	0.00	21	0.50	0.50	0.00
7	0.55	0.50	−0.05	22	0.30	1.10	0.80
8	1.00	1.90	0.90	23	1.20	0.80	−0.40
9	0.25	0.10	−0.15				
10	0.45	0.90	0.45	Average	0.59	0.72	0.13
11	0.20	0.45	0.25				
12	0.35	0.40	0.05				
13	0.60	0.65	0.05				
14	0.60	0.60	0.00				
15	0.60	0.60	0.00				

F=1.93. 5% point=4.1. 1% point=7.2.

Variance Analysis of Cereal Results

An analysis of all the wheat, oat and barley data by Fisher's variance method is shown in Table 5. In each test of significance the F value exceeds the 1% point by a large amount showing odds of well over 100 to 1 that the differences were conclusive. The analysis shows: First, that the three varieties representing three cereal crops reacted very differently; second, that the non-frosted plants gave, on the average, very significantly higher yields than did the frost injured plants; and third, that the differences between the yields of frosted and non-frosted plants were decidedly dissimilar among the three varieties.

TABLE 5.—VARIANCE ANALYSIS OF THE YIELDS OF PAIRED FROSTED AND NON-FROSTED PLANTS OF MARQUIS WHEAT, COLSESS BARLEY AND GOPHER OATS

Criteria	Sum of squares	Degrees of freedom	Mean square	F value	1% point
Crops	176.4	2	88.2	94	4.7
Treatments	49.0	1	49.0	51	6.8
Crop-Treatment interaction	32.9	2	16.5	18	4.7
Error	180.7	200	0.9		
Total	440.0	205			

Flax

Results on flax varieties are given in Table 6. A total of 69 plant pairs were taken in three varieties but in 39 cases the frosted plant did not survive the frost. Considering all of the 69 pairs the average yields of frosted and non-frosted plants were .43 gms. and .89 gms., respectively, with a difference of .46 gms. in favor of the non-frosted plants. Leaving out the pairs where the frosted plant yielded nothing owing to non-survival, the average yields of frosted and non-frosted plants were .44 gms. and .88 gms., respectively, with a difference of .44 gms. in favor of the non-frosted plants. The results are practically identical and show that the non-frosted plants yielded the same, whether the adjacent frosted plants under consideration survived or not. Six of the surviving frosted plants yielded more than the adjacent non-frosted ones, and these 6 were in the varieties W.R. 28 and Crown.

The results on the individual varieties of flax, showed large differences between the average yields of frosted and non-frosted plants. The difference was most marked in Bison, where the non-frosted plants yielded 170% more than the frosted. The comparable differences for Crown and W.R. 28 were 120% and 48%, respectively. A variance analysis was made on the results for each variety. The difference between the yields of frosted and non-frosted plants proved highly significant in Bison but not significant in the other two varieties.

TABLE 6.—INDIVIDUAL PLANT YIELDS (IN GRAMS) OF BISON, CROWN AND W. R. 28 FLAX PLANTS SEVERELY INJURED BY THE FROST OF JUNE 4TH COMPARED WITH THE YIELDS OF ADJACENT NON-FROSTED PLANTS OF THE SAME VARIETIES*

Variety	Plant pair number	Frosted	Non-frosted	Diff. favor non-frosted
Bison	1	0.60	2.55	1.95
	2	0.35	1.20	0.85
	3	0.55	0.80	0.25
	4	0.35	1.20	0.85
	5	0.15	0.50	0.35
	6	0.30	1.60	1.30
	7	0.40	0.75	0.35
	8	0.35	1.20	0.85
	9	0.30	1.00	0.70
	10	0.50	1.50	1.00
	11	0.30	0.35	0.05
	12	1.10	1.30	0.20
	Avg.	0.43	1.16	0.73
Crown	1	0.05	0.20	0.15
	2	0.20	0.15	−0.05
	3	0.20	0.90	0.70
	4	0.35	0.35	0.00
	5	0.20	0.60	0.40
	Avg.	0.20	0.44	0.24
W.R. 28	1	0.20	0.00	−0.20
	2	0.15	0.50	0.35
	3	0.60	1.60	1.00
	4	1.25	1.50	0.25
	5	0.60	1.00	0.40
	6	0.25	0.65	0.40
	7	0.20	0.15	−0.05
	8	0.20	1.00	0.80
	9	1.25	0.45	−0.80
	10	0.35	0.85	0.50
	11	0.20	0.80	0.60
	12	0.80	0.60	−0.20
	13	0.35	0.70	0.35
	14	0.60	0.50	−0.10
	Avg.	0.50	0.74	0.24

	F value	5% point	1% point
Bison	9.26	4.3	7.9
Crown	1.70	5.3	11.3
W.R. 28	2.68	4.2	7.7

*In addition to the plant pairs given in the table, there were 4 other pairs of Bison, 8 of Crown and 27 of W.R. 28 in which the non-frosted plant yieldded an average amount and the frosted plant yielded nothing owing to not surviving the frost.

The variance analysis of all of the flax results is given in Table 7 and shows that the differences between the yields of frosted and non-frosted plants as well as the varietal differences were highly significant. The interaction between varieties and treatments also appeared to be significant (the F value equalling the 5% point), thereby demonstrating that the yielding capacities of the varieties were influenced differently by the spring frost.

TABLE 7.—VARIANCE ANALYSIS OF THE YIELDS OF PAIRED FROSTED AND NON-FROSTED PLANTS OF THE FLAX VARIETIES, BISON, CROWN AND W.R. 28

Criteria	Sum of squares	Degrees of freedom	Mean square	F value	5% point	1% point
Varieties	3.90	2	1.95	9	3.1	4.8
Treatments	5.23	1	5.23	25	3.9	6.9
Variety-Treatment interaction	1.24	2	0.62	3	3.1	4.8
Error	20.65	102	0.20			
Total	31.02	107				

Results from Replicated Plot Tests

The possible relation between spring frost reaction and grain yield was investigated in the data obtained from four replicates of each of several rod row plot tests of varieties. In order to eliminate varietal effects, each of the yields and frost results was converted into a percentage of the mean yield or mean frost result, respectively, of the variety it represented. The correlation between yield and frost reaction was then determined. The correlation coefficients for the different tests are given in Table 8.

TABLE 8.—RELATION BETWEEN FROST REACTION AND YIELD IN PLOT TESTS

Number of varieties	Description of material	r S.E.
96	Lines of common wheat	0.07 ± 0.110
25	Common wheat varieties	0.22 ± 0.095
24	Varieties of common and durum wheat	0.02 ± 0.102
20	Varieties of barley	0.39 ± 0.095
16	Varieties of smooth awned barley	—0.05 ± 0.105
12	Varieties of oats	0.17 ± 0.180

It is apparent from Table 8 that there was no strong correlation between seedling reaction to the frost of June 4, 1935, and grain yield. In one wheat test and one barley test, the correlation appeared to be significant, but in both cases, the relation was relatively weak.

DISCUSSION

It is of interest to examine the individual plant data of Tables 2, 3, 4 and 6 in relation to the seedling frost data obtained on the plots as a whole and published recently by the writer (*1*). In Table 9, the cereal results are shown. The fairly high indices of frost resistance of Marquis and Gopher are reflected in the close approach the frosted plants made to the non-frosted plants in yield. The differences are quite small in spite of the fact that the frosted plants used were all injured fairly severely and, during their recovery, were in competition with plants which showed less injury. Undoubtedly the favorable growing weather immediately following the frost (see Table 1) was partly responsible. But in the case of Colsess, the difference in the yields of frosted and non-frosted plants was very large and this may be attributed to the fact that the frosted plants used were very severely injured.

TABLE 9.—THE FROST RATING OF LARGE CEREAL PLOTS IN RELATION TO THE YIELDS OF FROSTED AND NON-FROSTED PLANTS STAKED IN THOSE PLOTS

Variety	Mean index of seedling resistance to frost on a scale of 0 to 10	Mean yields of staked plants in grams		Mean per cent difference in yield in favor of non-frosted
		Frosted	Non-frosted	
Marquis	8.7	0.86	0.99	12
Gopher	8.6	0.59	0.72	22
Colsess	6.3	1.75	3.58	105

Previous studies (*2*, *3*, *5*) have shown that the injury to cereal and flax plants exposed, under controlled conditions, to sufficiently low sub-freezing temperatures at the seedling stage, is reflected in depressed yields as compared with unfrozen check material. The frosted plants in such studies are grown free from competition with non-frosted plants. Under yield conditions where the frost is only heavy enough to injure severely a small proportion of the seedlings (as for example, with Marquis and Gopher in this study) it may be that the surrounding plants take advantage of the temporarily weakened ones and yield more than they otherwise would, with the result that the total yield of the field is as large as it would have been had the frost not occurred. But when a large proportion of the plants in a field are frosted severely, the total yield is depressed, for the few uninjured plants cannot make up for the lower yields of the many injured plants. This is made clear by assuming a case where all of the plants are more or less severely injured; here the general yield is bound to be lowered to the full extent that the frost interferes with normal plant development.

TABLE 10.—THE FROST RATING OF LARGE FLAX PLOTS IN RELATION TO THE YIELDS OF FROSTED AND NON-FROSTED PLANTS STAKED IN THOSE PLOTS

Variety	Mean index of seedling resistance to frost on a scale of 0 to 6	Mean yields of staked plants in grams		Mean per cent difference in yield in favor of non-frosted
		Frosted	Non-frosted	
Crown	4.5	0.20	0.44	120
W.R. 28	4.3	0.50	0.74	49
Bison	3.4	0.43	1.16	170

The flax results are particularly interesting. The three varieties have been tested comparably for the past four years with the following yield results in bushels per acre: Crown 13.4, W.R. 28 12.7, and Bison 11.7. The difference between Crown and Bison proved to be quite significant statistically. In 1935, the results closely resembled those of the four year averages with Bison distinctly lower than the other varieties. The results given in Table 6 show Bison with decidedly higher yields of individual plants than either of the other varieties. The difference between the two sets of results is due largely to the fact that Bison, being less resistant to spring frost than Crown and W.R. 28, was left by the frost with a much thinner stand. The data presented recently by the writer (*1*) show in one test mean frost indices of 4.5, 4.3 and 3.4 for Crown, W.R. 28 and Bison, respectively, and in another 5.0 for Crown and only 3.2 for Bison. The individual plant yield data reported in the present paper, came from the plots in the first mentioned of these two tests. The data on stands in the plots of the varieties Crown and Bison show that the majority of the Bison plants were killed by the frost, whereas in Crown a large proportion of the plants survived. The reduced stand in Bison allowed the surviving plants to grow larger and yield heavier than the plants in the more crowded stands of the other varieties. Thus, the greatest difference between the

yields of frosted and non-frosted plants occurred in the most frost-susceptible variety (Bison), as was the case with the cereal varieties tested. The flax results on frost injury and yields are brought together in Table 10.

It is significant that the high individual yields of the Bison plants which survived the frost, did not compensate for the loss in stand caused by the death of the majority of the plants. The assumption, therefore, that the general yield of a field would be lowered under circumstances where a large proportion of the plants are severely frosted is borne out by the behavior of these three flax varieties, and Bison in spite of having the highest yields of individual non-frosted plants gave decidedly lower plot yields than either of the other varieties.

The comparative plot tests of cereal varieties showed very little relationship between the frost resistance data and the grain yields. This is not surprising in view of the fact that relatively few plants were severely injured and the majority of the plants were only moderately injured in most varieties. Ivanov (*3*) found that frosts of −3° C. to −5° C. actually resulted in increased yields in oats and barley, whereas exposure to more severe freezing reduced the yields decidedly. In the present study, the frost recorded at a distance of 1,200 feet from the cereal nursery and at about the same elevation, was between 27° F. and 28° F., which is only −3° C., and the duration of that temperature was relatively brief. It is, therefore, quite probable that the stimulating effect of slightly sub-freezing temperatures may have caused the more frost-resistant plants in the variety plots to yield more than normally, and thereby partially counteract the effect of the frost in depressing the yields of the frost-susceptible plants, with the result that the net yields of the plots showed little relation to the average seedling frost damage recorded in June. However, the correlations of seedling frost reaction with the grain yields in the replicated tests of common wheat varieties and barley varieties were both significant. These results indicate that larger correlations could be expected under conditions where the frost damage to seedlings is more severe.

From the plant breeding viewpoint, the present study has shown that spring frost resistance in spring sown grain crops is of economic importance. There is little the northern grain grower can do in the way of changing his management procedure to avoid damage to his crops from spring frost. Greater returns in farming, as far as spring frost is concerned, therefore, depend almost wholly upon the plant breeder.

SUMMARY

1. A study was made of the grain yields of plants which in the seedling stage were badly injured by a spring frost, as compared with the yields of adjacent plants which showed no injury.

2. The relation of seedling frost injury and grain yield was also examined in a number of replicated comparative rod row plot tests of cereal varieties.

3. The average yields of individual frost-injured plants proved to be very significantly lower than the average yields of the adjacent non-injured plants in Colsess barley and Bison flax.

4. The difference between the average yield of injured and non-injured plants was much larger in Colsess barley and the three flax varieties than in Marquis wheat or Banner oats.

5. Among the three flax varieties and among the three cereal varieties there were significant differences in yield losses attributable to the frost.

6. Plot yields were found to be either not correlated or else only weakly correlated with the seedling frost injury notes.

LITERATURE CITED

1. Harrington, J. B. 1936. Varietal resistance of small grains to spring frost injury. Jour. Amer. Soc. Agron. *28* : 374-388. 1936.

2. Ivanov, S. M. 1935. The response of spring crops to low temperatures. Bull. Appl. Bot. Gen. Pl. Br. Ser. *3* : 163-198. In Russian.

3. ————————. 1935. The response of spring crops to spring frosts. Bull. Appl. Bot. Gen. Pl. Br. Ser. *3* : 199-220. In Russian. English summary, pp. 14-15.

4. Peltier, G. L. and Kiesselback, T. A. 1934. The comparative cold resistance of spring small grains. Jour. Amer. Soc. Agron. *26* : 681-687.

5. Rzhavitin, V. N. 1935. Resistance of different flax varieties to spring frosts and the influence of the latter on growth, development and yield of flax. Bul. Appl. Bot. Gen. Plt. Br. Ser. *3* : 227-234. In Russian. English summary pp. 16-17.

6. Waldron, L. R. 1932. Differences of injury by frost to wheat plants grown comparably. Jour. Amer. Soc. Agron. *24* : 494-500.

Résumé

L'effet des gelées du printemps sur les rendements du grain semé au printemps. J. B. Harrington, Université de la Saskatchewan, Saskatoon, Sask.

Il a été fait une étude des rendements de grain donnés par des plantes qui avaient été fortement endommagées par une gelée de printemps dans les premières phases de la végétation, et ces rendements ont été comparés à ceux de plantes adjacentes qui n'avaient subi aucun dommage. La relation entre les dommages causés par la gelée et le rendement de grain a été examinée également dans un certain nombre de parcelles d'essais comparatifs de variétés de céréales semées en rangées. On a constaté pour l'orge Colsess et le lin Bison que les rendements moyens des plantes abîmées par la gelée, prises séparément, étaient beaucoup plus faibles que ceux de plantes adjacentes, non endommagées. La différence entre le rendement moyen des plantes endommagées et des plantes non endommagées était beaucoup plus forte dans l'orge Colsess et les trois variétés de lin que dans le blé Marquis ou l'avoine Banner. Entre les trois variétés de lin et les trois variétés de céréales, il y avait une différence très importante de rendements, et ces différences pouvaient être attribuées à la gelée. On a constaté que les rendements des parcelles d'essais ne pouvaient être reliés aux dommages causés par la gelée aux jeunes plantes, ou du moins que la corrélation n'était que très faible.

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THE IMPERIAL BUREAU OF PLANT GENETICS[1]

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The enormous magnitude of agricultural literature and the lack of any organized system for dealing with it was one of the subjects of discussion at the Imperial Agricultural Conference held in London in 1927. The solution arrived at by the Conference was the system now known as the Imperial Agricultural Bureaux, which were the direct outcome of the Conference, though most of them did not begin to function until some time in 1929. Eight Bureaux were established to cover different branches of agricultural science, each Bureau being located at some established centre of research in the branch in question. The Imperial Bureau of Plant Genetics was very naturally attached to the Plant Breeding Institute of the University of Cambridge.

The object of the Bureaux is to act as central clearing-houses of agricultural information, which is obtainable from a wide range of very varied sources. Take for instance the agricultural literature alone. The library of the School of Agriculture at Cambridge receives every year some five hundred periodical publications and nearly twice as many non-periodical publications such as bulletins, reports, etc., not to mention the large number of books which are naturally always coming in. It is obviously quite impossible for any individual investigator to keep in touch with all these publications by his own unaided effort—indeed, in Plant Breeding alone, excluding Genetics and Cytology, the articles published in 1930 covered 4,025 pages and it has been calculated that a plant breeder would have to read eleven printed pages a day in order merely to keep up with the papers in his own restricted subject. And nowadays no research worker can afford to confine his reading to his own particular subject, for the sciences are impinging one upon the other to an ever greater degree. A plant breeder to-day has even more necessity of keeping in touch with recent developments in genetics than in plant breeding proper, and the dividing line between genetics and cytology has become so far obliterated that the two subjects have come to be regarded as the same science. Plant genetics has of late also become very much linked up with plant physiology and will inevitably become more so in the not far distant future.

The plight of the agricultural worker is further aggravated by the difficulty of language. Before the War scientific papers were usually written in either English, French or German, occasionally also in Italian, and scientists were legitimately expected to have at least a working knowledge of these languages. Not so to-day—a wave of nationalism has swept the world since the War and even so pacific a pursuit as agricultural research has not escaped its baleful consequences, for to-day it is not unusual to find papers of scientific importance appearing in Ukrainian, Hungarian, Finnish, Portuguese, to take a few at random, not to mention the enormous quantity of literature that now appears in Russian, and another group of ever increasing dimensions in Japanese and latterly also Chinese.

It is beyond the capacities, then, of any one individual to deal in a satisfactory way with this volume of literature, and indeed for a single institution or even country to do the work for itself is a practically impossible task. Some form of co-operative effort has become essential.

Now the British Empire happens to be peculiarly favourably situated for the solution of this problem. As a far-flung system of countries scattered over the surface of the globe, with a preponderance of agricultural interests. it is possible for the British Empire to organize a central system on lines which would be impracticable for any one of the participating countries acting individually. The Imperial Bureaux act as central clearing-houses for the use of the whole Empire. All Empire countries, with few exceptions, contribute towards their maintenance, and all are entitled to their services. The agricultural literature of the whole world is collected and sifted at a central point and then distributed, in a suitable form, to research workers all over the Empire. The first stage in this work is that the agricultural publications of the whole world are collected and surveyed, all relevant articles are noted and included in a card catalogue which is permanently available for consultation by Empire workers. The second stage is the dissemination of this information to the workers overseas with the least possible loss of time. Experience has shown that mere lists of titles are of comparatively little use—the title is often ambiguous or misleading; most provincial and overseas libraries, however excellent, are without a considerable number of the publications referred to; and last but not least, even when access can be had to the original this is not infrequently unintelligible to the researcher on account of the language in which it is written. The experience of the genetics Bureau showed at the end of a few months that the most useful service of any was the supply of English abstracts of all the relevant papers. Ever since 1930 this has been done in the form of a quarterly abstract journal, *Plant Breeding Abstracts*, which brings together all the papers of any value whatever on the breeding, genetics and cytology of crop plants. The abstracts are written in English and a special feature distinguishing this from other abstract journals of a similar nature is the inclusion of particularly full résumés of the papers written in Russian and others of the more obscure languages. *Plant Breeding Abstracts* has become the standard work of its kind. It is now in use by geneticists and agricultural research bodies throughout the world, and specialist journals of the most varied kind reproduce abstracts from *Plant Breeding Abstracts* in their pages.

The Bureau thus has a double function: firstly to collect and maintain a permanent record of all the existing information, and secondly to make this known to its users through the medium of published abstracts and other bibliographical documents. The permanent record is kept in the form of a card catalogue, which naturally contains a great many entries not deemed of sufficient importance or general interest to be included in the abstract journal. The catalogue is available for consultation, in person or by correspondence, by all research workers in the Empire. With its aid the innumerable enquiries received from workers all over the Empire are answered. These enquiries vary in nature; some are quite straight-

[1] Reprinted from the Institut International de Documentation.

[2] Deputy Director Imperial Bureau of Plant Genetics (For Crops Other than Herbage).

forward requests for information on a particular point, many consist of requests for references to the literature on a special branch of the subject that the enquirer happens to be interested in, whilst some are on more obscure points and involve a considerable amount of searching, scrutiny of the literature and often correspondence to enable them to be answered satisfactorily. Some particularly all-embracing enquiries have been dealt with, such as one for all references existing on the breeding of sugar beets, mangels and swedes, another from Leningrad for all the literature on breeding for disease resistance, and one peculiarly enthusiastic but almost unwarrantably optimistic enquirer made a request for "all the literature on breeding and genetics of cultivated plants and grasses" but unfortunately had to be refused! The Officers of the Bureau are in an unique position for appreciating the trends of development in the different branches of the subject and from time to time the position of research in particular branches is reviewed in bibliographical monographs consisting in a survey of the literature up to date with full lists of the references on which the survey is based. The surveys consist of discussions of the results and contributions of the principal investigators and outline the present position of research in the particular subject. Though not critical, these bibliographical monographs represent one of the most constructive contributions of the Bureau to the science and its advancement. One of these, the joint Bulletin on Vernalization, was the means of making known for the first time to the European public a new method of artificially accelerating maturity which has aroused world-wide interest and of which the details are still available only in Russian. The subjects for these monographs are chosen by consideration of the relative interest and importance of the different branches to Empire workers and many of them have been compiled in response to definite requests or enquiries from correspondents.

Another service offered by the Bureau is the supply of translations or extended abstracts of foreign papers of special importance. By means of correspondence and personal contact the Bureau is able to keep in touch with its users and issue these extended abstracts with discrimination, knowing the general needs of the majority of the workers in the Empire. The value of this branch of the Bureau's activity is the subject of a number of letters of thanks and congratulation, of which the following is a specimen:

"I am very much indebted to you for your letters of the 4th and 10th of July, with enclosure. The Air Mail letter of the 10th July was particularly welcome as just about the time of its arrival I was settling down to the long job of writing up a detailed description of my Noble × S. Munja crosses not knowing that Rumke had already done this and so I was able to switch off on to other work. But for your help I might have wasted a great deal of time.

"The abridged translation of Rumke's paper was exceedingly interesting and as far as I can see at present his hybrids are similar to ours.

"

. . . . . .

"Again thanking you for all the help you so often give us."

To further this spirit of active co-operation, overseas officers on leave in England are encouraged to visit the Bureau to discuss their problems and tours are occasionally arranged for Bureau officers to visit Empire

countries, as when the Deputy Director of the Genetics Bureau made a tour of the Research Stations of India and Ceylon in the winter of 1933/34. It is believed that much of the success of the Bureau system depends on this spirit of personal contact and service, which differentiates it from other organizations of a similar kind. The officers of the Bureaux, in addition to their linguistic abilities, are mostly highly qualified scientists and specialists in the particular fields which they cover and so are able to take an active and constructive part in the development of the science. Each Bureau is located at a recognized centre of research in its field and thus has constant access to the experts of the subject, whose advice it can always seek in case of need. The Genetics Bureau, in addition, is fortunate in having the co-operation of the Department of Statistics of the University of Cambridge, whose Reader furnishes all the abstracts for the section on field experimentation and applied statistics in *Plant Breeding Abstracts*, and renders other valuable service to the Bureau in consultation. *Plant Breeding Abstracts* also reviews all the newly published books on Plant Genetics and Cytology and on a number of cognate subjects. The section of the abstracts devoted to Forest Genetics, a subject which has only begun to engage the attention of silviculturists in the last few years, is also one of growing importance and many of the references, as commented on by the leading forest journal of this country, *Forestry*, are "from publications not ordinarily seen by foresters."

Throughout the work of the Imperial Bureau of Plant Genetics the system of classification used is the Universal Decimal Classification. The card catalogue is arranged on this system, as it is found to lead to ease of filing and of searching; the abstracts in *Plant Breeding Abstracts* are arranged decimally as this leads to ease of compilation and affords an automatic and rational means of classifying the abstracts in each quarterly number. They are also thus classified ready for filing and many of our correspondents have adopted the Decimal System and file our abstracts without having to evolve their own system of classification. It also affords an efficient means of compiling the annual index to the volume, in which the entries are arranged decimally and are thus classified without further ado. Cumulative indexes on these lines are issued at the completion of each volume and constitute a miniature of the card catalogue and are in constant use for reference. In 1930 an English translation of the agricultural section of the Universal Decimal Classification was published by the Bureau and the demand for this has been so great that a reprint was called for in 1932.

The above gives an idea of the main functions of the Imperial Bureau of Plant Genetics, though in the course of its activities the Bureau is called upon to perform many and various other duties. Among these are the arrangement of visits to this country for overseas workers wishing to make the best use of their time, and the many arrangements that have been made for putting investigators in one part of the world in touch with workers in allied fields elsewhere. The Bureau is not infrequently even called on to arrange exchanges of seed material and one such request of an exceptional nature has involved the maintenance of a large number of tubers of South American potato species on the University Farm, Cambridge, in order that specimens of them could be distributed to research stations in a number of different Empire countries.

THE ECONOMIC ANNALIST

A REVIEW OF AGRICULTURAL BUSINESS PREPARED BI-MONTHLY BY THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA

Vol. VI, No. 3 June, 1936

THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, LARGELY FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

The index of wholesale prices in Canada showed a slight recession in both March and April, the index for April being 72.2 compared with 72.5 in April, 1935. Animals and their products declined from 70.5 in March to 69.8 in April. Changes in the other groups were materially less. Slight gains were indicated for wood, wood products and paper, iron and its products and chemicals and allied products. The index of Canadian farm products was one point lower in April as compared with February and half a point lower than it was in March.

Retail Prices.—After showing a slight advance in March, the index of retail prices dropped to 79.8 in April. Lower prices of food and fuel were the chief factors in the decline. Retail sales in March were 3.2% higher than in February and 3.5% above sales in March of last year.

Agricultural Products.—Prices of grain continued to fall but prices of potatoes and other field products rose and the index for March was 59.2 and that for April 59.8 which is still well above the index of 57.3 reported in April, 1935. Prices of live stock are higher than a year ago but have shown a distinct tendency toward lower levels, the index falling from 72.1 in February, 1936, to 70.5 in March and 69.8 in April comparatively heavy deliveries and weakening of prices of cattle in United States being largely responsible. Exports of cattle to the United Kingdom have been resumed on a very substantial scale. Prices of sheep and lamb have been relatively good.

Physical Volume of Business.—Indexes of physical volume of business in the first four months of 1936 were substantially higher than in the corresponding period of 1935 although there has been a tendency to slightly lower levels from month to month. This is also true of the index of industrial production. The index of manufacturing showed an increase in March as compared with February. Marketings of grain and live stock advanced from 62.7 to 89.5. Larger shipments of wheat, oats, and rye contributed to the increase in grain marketings and this was the chief cause of the rise in the index. The figures for April have been added since the foregoing was written.

Prices in United Kingdom.—The index numbers of prices of agricultural produce (1911–13 = 100) was 118 in February compared with 119 in January. This index does not take into consideration payments under the Wheat Act of 1932 and the Cattle Industry Act, 1934. Prices of bacon, pigs, eggs and cheese advanced. Store pigs, fat sheep, dairy cows, store cattle, barley and oats were lower. If the payments under the two Acts referred to previously are taken into consideration, the index would have been 123 in February compared with 125 in January.

Prices in United States.—Prices of beef cattle in the United States averaged $6.27 per hundredweight in April of this year compared with $6.71 in April, 1935. Hogs averaged $9.38 per hundred pounds as against $7.88 in April of last year. Prices

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION
COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62.6	56.4	77.0	65.4				
1914	65.5	69.2	64.9	79.0	66.0				
1915	70.4	77.7	76.9	79.2	67.3				
1916	84.3	89.7	88.4	92.3	72.5				
1917	114.3	130.0	134.3	119.6	85.6				
1918	127.4	132.9	132.0	134.7	97.4				
1919	134.0	145.5	142.4	152.5	107.2	71.3	65.5	48.1	47.1
1920	155.9	161.6	166.5	149.9	124.2	75.0	69.9	52.6	94.2
1921	110.0	102.8	100.3	108.5	109.2	66.5	60.4	65.2	86.4
1922	97.3	86.7	81.3	99.1	100.0	79.1	76.9	82.6	82.8
1923	98.0	79.8	73.3	95.1	100.0	85.5	83.8	91.4	87.6
1924	99.4	87.0	82.6	97.2	98.0	84.6	82.4	102.5	114.9
1925	102.6	100.4	98.1	105.7	99.3	90.9	89.7	97.2	108.6
1926	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1927	97.7	102.1	99.9	105.7	98.4	106.1	105.6	103.6	110.0
1928	96.4	100.7	92.6	114.3	98.9	117.3	117.8	146.7	112.8
1929	95.6	100.8	93.8	112.5	99.9	125.5	127.4	101.1	109.6
1930	86.6	82.3	70.0	102.9	99.2	109.5	108.0	103.0	128.4
1931	72.2	56.3	43.6	77.6	89.6	93.5	90.4	99.0	125.7
1932	66.7	48.4	41.1	60.7	81.4	78.7	74.0	114.3	120.1
1933	67.1	51.0	45.8	59.7	77.7	79.7	76.8	105.1	115.4
1934	71.6	59.0	53.8	67.7	78.9	94.2	93.6	88.5	114.2
1935	72.1	63.4	57.1	73.9	79.3	102.4	103.3	87.4	128.4
1935									
Jan.	71.5	61.4	55.7	71.0	78.8	97.5	97.8	30.6	143.7
Feb.	71.9	62.0	55.7	72.6	78.9	100.6	101.1	62.2	141.2
Mar.	72.0	62.7	56.4	73.3	78.8	94.2	93.3	65.4	143.2
Apr.	72.5	64.7	59.8	72.9	78.6	98.3	97.7	91.8	135.8
May	72.3	64.1	58.0	74.4	78.6	103.2	104.4	86.3	123.2
June	71.5	61.4	55.1	72.0	78.8	99.2	99.7	106.1	125.0
July	71.5	61.5	55.7	71.1	78.8	103.0	104.0	164.7	114.8
Aug.	71.6	61.8	55.5	72.4	79.4	107.9	110.3	163.9	117.0
Sept.	72.3	64.7	58.3	76.5	79.6	101.9	102.5	114.2	117.2
Oct.	73.1	65.8	59.3	76.7	80.4	107.2	109.5	86.6	119.7
Nov.	72.7	65.0	57.8	77.1	80.6	110.0	113.5	43.3	127.1
Dec.	72.6	65.4	57.9	77.9	80.6	106.2	108.8	34.0	133.4
1936									
Jan.	72.9	65.9	59.0	77.5	80.7	105.2	107.0	39.8	143.4
Feb.	72.5	66.0	58.9	77.8	80.4	104.9	104.9	62.7	150.3
Mar.	72.4	65.5	59.2	76.0	80.5	103.3	104.1	89.5	149.5
Apr.	72.2	65.0	59.8	73.8	79.8	108.8	109.2	115.8	149.3

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1934, p. 15.
2. Wholesale prices of Canadian products of farm origin only. See Prices and Price Indexes 1913-1934, p. 52, and Monthly Mimeographs 1934 and 1935.
3. Wholesale prices of grains, fruits and vegetables.
4. Wholesale prices of Animals and Animal Products.
5. Including foods, rents, fuel, clothing and sundries. See Prices and Price Indexes 1913-1928, pp. 181-185, 290-293. 1926 = 100.
Prices and Price Indexes 1913-1934, p. 117, and Monthly Mimeographs, 1934-1935.
6. Monthly Review of Business Statistics, p. 8, and Monthly Indexes of the Physical Volume of Business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

of butter averaged 28.3 cents per pound in April this year compared with 29.8 cents in April, 1935. Potatoes were 81.1 cents per bushel as against 49.1 cents in April of last year. Chickens averaged 16.9 cents per pound compared with 15.5 cents last year.

SOME FACTS CONCERNING MILK CONSUMPTION IN CANADA[1]

G. P. BOUCHER[2]

An analysis of records obtained from 3,213 families in various urban and rural areas during a survey conducted in the summer of 1935 shows a per capita consumption of milk of about .74 pints per day. The survey was undertaken by the Economics Branch and the Dairy Branch of the Dominion Department of Agriculture in co-operation with the Quebec and Alberta Departments of Agriculture. It dealt with the consumption of milk and cheese in relation to locality, income, national type, occupation and various other factors.[3]

The areas visited were the City of Quebec in the Province of Quebec, the City of Oshawa in the Province of Ontario, the City of Calgary in the Province of Alberta and some villages and farm communities in each of these provinces. The data obtained are considered to be fairly representative of cheese and milk consumption in the three provinces mentioned and it is hoped that they also give a fairly accurate picture of conditions in Canada as a whole.

This article is designed to give only some of the results concerning milk consumption. Table 1 shows the daily per capita consumption of milk and the amount used as a beverage in various localities. Of the three cities, Quebec City shows a somewhat lower per capita consumption with a higher proportion of milk being utilized as a beverage, which may be partly explained by the fact that families are very much larger in that city.

TABLE 1.—DAILY PER CAPITA CONSUMPTION OF MILK AND AMOUNT USED AS A BEVERAGE IN VARIOUS LOCALITIES OF CANADA, 1935

Locality	Number of families	Number of persons	Per capita consumption per day		
			Total consumption	Used as a beverage	Proportion used as a beverage
			(pints)	(pints)	%
Cities					
Oshawa	816	3,365	0.71	0.37	52
Quebec City	790	4,686	0.68	0.50	73
Calgary	996	3,995	0.74	0.44	59
Totals or averages for cities	2,602	12,046	0.71	0.44	62
Villages					
Uxbridge	102	345	0.73	0.34	47
St. Romuald	48	287	0.40	0.22	54
Claresholm	101	432	0.70	0.39	56
Totals or averages for villages	251	1,064	0.63	0.33	52
Farm Areas					
Ontario rural cheese producing area	50	222	0.96	0.47	49
Ontario rural non-cheese-producing area	52	236	0.85	0.30	35
Quebec rural cheese producing area	49	361	1.20	1.01	84
Quebec rural non-cheese-producing area	108	772	0.74	0.55	75
Alberta rural area	101	407	1.40	0.81	58
Totals or averages for farm areas	360	1,998	1.00	0.65	65
Grand totals and averages	3,213	15,108	0.74	0.46	62

[1] Preliminary statement subject to revision and correction.
[2] Field Assistant Economics Branch Department of Agriculture, Ottawa.
[3] The author gratefully acknowledges the assistance of Miss B. Shuart in the statistical analysis of the data.

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Of the three villages, Saint Romuald, in the Province of Quebec, also shows a much lower per capita consumption of milk, while the proportion which is utilized as a beverage is not much different from the average for the three villages. It will be noted that although only about half as many families were interviewed in Saint Romuald as in other villages, it is believed the figures are representative of conditions in that village.

The farm areas in Quebec and Ontario have been divided into cheese-producing and non-cheese-producing areas. The cheese-producing area of Quebec includes the two parishes of St. Pierre and Ste. Famille on the Island of Orleans and the non-cheese-producing area is the Parish of Ancienne-Lorette. In Ontario, the Belleville farm area has been chosen as the cheese-producing area and Columbus and the Oshawa farm area as the non-cheese-producing area. No such division has been made in Alberta.

TABLE 2.—DAILY PER CAPITA CONSUMPTION OF MILK AND AMOUNT USED AS A BEVERAGE AS RELATED TO FAMILY INCOME, 3,213 FAMILIES IN THE PROVINCES OF QUEBEC, ONTARIO AND ALBERTA, 1935

Family income	Number of families	Number of persons	Per capita consumption per day		
			Total consumption	Used as beverage	Proportion used as beverage
			(pints)	(pints)	%
On Relief	189	921	0.54	0.31	57
Under $1,000	1,263	5,868	0.69	0.43	62
$1,000–$2,000	1,060	4,978	0.76	0.47	62
$2,000–$4,000	544	2,486	0.81	0.50	62
$4,000 and over	151	826	0.95	0.63	67
Not stated	6	29	0.97	0.55	57

There was a definitely higher consumption of milk and higher utilization of milk as a beverage in the rural cheese-producing areas. The average consumption of milk was higher in the farm households and in city homes than in village homes. For the 3,213 families studied, the per capita consumption of milk per day was .74 pints and the utilization of milk as a beverage, .46 pints. The amount used as a beverage represented 62% of all the milk consumed.

TABLE 3.—DAILY PER CAPITA CONSUMPTION OF MILK AND AMOUNT USED AS A BEVERAGE AS RELATED TO NATIONAI TYPES, 3,213 FAMILIES IN THE PROVINCES OF QUEBEC, ONTARIO AND ALBERTA, 1935

National types	Number of families	Number of persons	Per capita consumption per day		
			Total consumption	Used as a beverage	Proportion used as a beverage
			(pints)	(pints)	%
Canadian	1,153	4,609	0.79	0.44	56
French Canadian	967	5,957	0.70	0.51	73
English and Welsh	482	1,832	0.77	0.41	54
Irish and Scotch	289	1,205	0.77	0.44	57
American	69	298	0.85	0.49	58
Ukrainian	84	403	0.77	0.45	59
Jewish	27	122	0.57	0.31	54
German	23	132	0.66	0.29	43
Others	116	542	0.61	0.36	59
Not stated	3	8	0.65	0.33	50

There is a very direct relationship between consumption of milk and family income (Table 2). The proportion of milk used as a beverage is exactly the same for families with incomes varying from less than $1,000 to $4,000, somewhat lower for families on relief and proportionately higher for families with incomes of over $4,000.

TABLE 4.—DAILY PER CAPITA CONSUMPTION OF MILK AND AMOUNT USED AS A BEVERAGE AS RELATED TO OCCUPATION, 3,213 FAMILIES IN THE PROVINCES OF QUEBEC, ONTARIO AND ALBERTA, 1935

Occupation group	Number of families	Number of persons	Per capita consumption per day		
			Total consumption	Used as a beverage	Proportion used as a beverage
			(pints)	(pints)	%
Professional	315	1,492	0.82	0.55	67
Large business executive	268	1,214	0.82	0.50	61
Small business executive	157	747	0.75	0.48	64
Salesman	191	936	0.74	0.49	66
Clerical work	308	1,397	0.75	0.49	65
Skilled labour	855	4,127	0.68	0.41	61
Unskilled labour	484	2,321	0.57	0.33	58
Farmer	333	1,751	1.04	0.67	64
Retired	168	500	0.70	0.29	42
Not stated	134	623	0.59	0.35	59

Table 3 shows the relation between consumption and national types. This classification by national types is a rather broad one. The term "Canadian," for instance, may and does include a number of families that might well have been listed as English, Welsh, Scotch or Irish, and vice versa. However, the striking similarity between the amounts of milk consumed by each of these national types suggests that all people of British origin might have been grouped together. The French-Canadian group, which is mostly from the Quebec area, shows the highest proportion of milk used as a beverage.

A study of the relation between milk consumption and occupation shows the farmer group coming first with a daily per capita consumption of 1.04 pints (Table 4). There is a very noticeable similarity between the milk consumption habits of the small business executive, salesmen and clerical groups. The consumption of milk by labourers is the lowest with the unskilled labour group showing a daily consumption of only .57 pints.

ANTIGONISH COUNTY, NOVA SCOTIA. A Study of Land Utilization, Farm Production and Rural Living; W. V. Longley and W. F. Chown. Bulletin No. 118, Nova Scotia Department of Agriculture.

Antigonish County, in Eastern Nova Scotia, has experienced a greater decrease of rural population than any other of the 34 counties in Eastern Canada that reached their maximum in the census year 1881. The burden of maintaining schools and other municipal services is a heavy one to be borne by the present population. This has been increased latterly by the low prices received for primary products and by the lack of opportunity for the youth of the county to find remunerative employment in other parts of Canada and the United States.

The Antigonish County bulletin presents the results of a study of the causes leading to the present situation, a survey of economic and social conditions at the present time and an examination of the possibilities of increasing farm and county revenues and curtailing municipal expenditures by a program based on the better utilization of land for agricultural and forest production.

A STUDY OF 126 ABANDONED FARMS IN THE LOMOND AREA OF SOUTHERN ALBERTA[1]

W. N. WATSON[2]

The chief agricultural problems of the abandoned farm area of Southern Alberta are those which are characteristic of land abandonment throughout Western Canada's dry lands. The population on the drier areas of the West has been a non-permanent one since the very beginning of settlement. When these lands were opened up for settlement occupation was very rapid. Little was known of the nature of the soil, climate, insect pests, and other factors which would vitally affect the agricultural development of the district. The first settlers had to develop dry farming methods by trial and error. Early failures on the poorer farms therefore were inevitable. Unfortunately successive operators took up the abandoned farms largely through lack of knowledge of the problems which faced them. The costs involved in such settlement have been prodigious and cannot be measured in dollars and cents only, because much human privation followed failure on these farms.

Geographic Setting.—In 1863 Palliser in his report to the British Government on the resources of Western Canada described a triangular area (later known as Palliser's Triangle) having its base on the International Boundary lying between longitude 102 degrees W. (Turtle Mountain, Manitoba) and 114 degrees W. (Cardston, Alberta), and its apex on latitude 52 degrees N. (Saskatoon, Saskatchewan). He said that within this area successful farming would be impossible. The Lomond area lies near the south-western corner of Palliser's triangle. It includes that area which has for its boundaries the Little Bow River and Lake McGregor on the West, the Bow River on the East, Township 17 on the North, and the Old Man River on the South, excluding the irrigated area in the South-eastern corner. It includes the district adjoining the villages of Lomond, Travers, Enchant and Retlaw. During July and August, 1935, information was collected on 126 abandoned farms in the Lomond area as a part of the Land Utilization Survey of the Vulcan-Lomond area of Southern Alberta. This study was conducted by the Economics Branch of the Dominion Department of Agriculture in co-operation with the University of Alberta and the Alberta Provincial Department of Agriculture. It is a part of the program being carried out under the Prairie Farm Rehabilitation Act of 1935 and most of the funds were supplied under the provisions of this Act. A detailed description of the area, the climate, soils, people, history, etc., will be included in the major report of the Land Utilization project, and is, therefore, not presented here. It was impossible to get details of all the abandoned land in the area. However, the 126 abandoned farms concerning which information was obtained offer a cross-section of abandonment, and enable one to form a reasonably accurate picture of the nature of the abandonment which has taken place in the area.

Dates of Settlement.—The Lomond area was thrown open to homesteaders by the Dominion Government in 1906. Previous to that time the land was used by

TABLE 1.—DISTRIBUTION OF 126 ABANDONED FARMS IN THE LOMOND AREA OF ALBERTA ACCORDING TO YEARS IN WHICH LAND WAS FIRST FARMED

—	1906–1910	1911–1915	1916–1920	1921–1925	1926–1930	1931–1935	Known	Not known
Number of farms	62	9	7	6	1	5	90	36
Percentage	69	10	8	7	1	5	100	
Cumulative percentage	69	79	87	94	95	100	100	

[1] These data were obtained in a study of land utilization in South Central Alberta begun in 1935. Preliminary statement, subject to revision and correction.

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ranchers only. A complete history of 90 farms was secured, and of these 69% were first farmed before 1910 and 79% were first farmed before 1915; 87% of the farms were first farmed twenty years or more ago. The average number of years since the date of settlement was 23.08. Only 6% of the farms were brought under cultivation within the last ten years. The more recently acquired virgin land was obtained from the various land companies. Thus the wave of settlement was well under way before the opening of the Great War and the period of high prices for agricultural products. The rapidity with which the area was settled was the result of the Dominion Government's open immigration policy, free land, and the fact that most of the better lands of the West had been homesteaded. "The last best west" was the cry. It is important to note, however, that in spite of evidence of unsuccessful settlement, some individuals continued to file on the land throughout the whole period since 1906.

TABLE 2.—METHOD OF ACQUISITION BY FIRST OPERATOR, 126 ABANDONED FARMS, LOMOND AREA OF ALBERTA

—	Homestead and pre-emption	Purchased from				Known	Not known	Total
		Can. Pacific Railway	Hudson's Bay Co.	Government	Canada Land Co.			
Number of farms	102	3	6	4	1	116	10	126
Percentage	88	3	5	3	1	100		
Cumulative percentage	88	91	96	99	100	100		

The years 1903 to 1910 were considerably drier than average, and it may be wondered why, in spite of this, settlement was so active. However most of the homesteads were taken up after 1908, and hence little land was seeded to crops until 1911. Low yields, therefore, were not in evidence to discourage settlement. In 1911, ample moisture fell, and much better than average rainfall continued until 1917.

Method of Acquisition by First Operator.—The land open to homestead and pre-emption was almost entirely filed upon by 1911 except for a few cancellations. The remaining farms were obtained by purchase from the Canadian Pacific Railway Company, the Hudson's Bay Company, the Dominion Government (School Lands), and the Canada Land and Irrigation Company. Table 2 shows that 88% of the abandoned farms were homesteads and pre-emptions.

Years Farmed.—Twenty-four per cent of the holdings were farmed less than five years, and 40% less than ten years. Only one of the farms had been in operation continuously up to 1934.

TABLE 3.—NUMBER OF YEARS FARMS HAVE BEEN OPERATED, 126 ABANDONED FARMS, LOMOND AREA OF ALBERTA

—	1–5	6–10	11–15	16–20	21–25	26–30	31–35	Known	Not known	Total
Number of farms	16	11	15	10	14	1	1	68	58	126
Percentage	24	16	23	14	21	1	1	100		
Cumulative percentage	24	40	63	77	98	99	100	100		

Twenty-eight per cent of the farms had only one operator (Table 4). Some of these men were speculative homesteaders who took poor land by mistake, failed in their efforts at farming and moved off. A few of them did not remain long enough

TABLE 4.—NUMBER OF OPERATORS ON EACH FARM, 126 ABANDONED FARMS, LOMOND AREA OF ALBERTA

No. of operators	1	2	3	4	5	6	Known	Not known	Total
Number of farms	26	38	25	3	2	1	95	31	126
Percentage	28	40	26	3	2	1	100		
Cumulative percentage	28	68	94	97	99	100	100		

to complete the Government's requirements before title to the property was granted. Thirty-two per cent of the farms had three or more operators. These were probably operated in a haphazard manner. They were cultivated for a few years on the get-rich-quick plan, abandoned, rented or sold when conditions looked more favorable, and the cycle was repeated several times.

Of those who operated the farms last, 59% operated them five years or less (Table 5). More than one-quarter of them were operated for one year only. However, the fact that 11% were operated sixteen years or more is highly significant. There are factors which do make it possible for certain farmers to carry on for long periods of time under the most adverse conditions.

TABLE 5.—NUMBER OF YEARS FARMS WERE OPERATED BY LAST OPERATOR, 126 ABANDONED FARMS, LOMOND AREA OF ALBERTA

Years	1	2	3	4	5	6–10	11–15	16 and over	Known	Not known	Total
Number of farms	22	15	7	3	3	16	9	10	85	41	126
Percentage	27	18	8	3	3	20	10	11	100		
Cumulative percentage	27	45	53	56	59	79	89	100	100		

Homesteaders formed 27% of the last operators; 34% were renters; 38%were purchasers. Homesteaders were those who remained on the farm longest; purchasers next longest, and renters remained for the shortest period. A comparison of Table 1 with Table 6 shows the very large increase in the number of renters.

TABLE 6.—METHOD OF ACQUISITION OF FARM BY LAST OPERATOR, 126 ABANDONED FARMS, LOMOND AREA OF ALBERTA

—	Homestead pre-emption	Rented	Purchased	Legacy	Known	Not known	Total
Number of farms	25	32	36	1	94	32	126
Percentage	27	34	38	1	100		
Cumulative percentage	27	61	99	100	100		

Most of the farms were fairly well supplied with school facilities (Table 7). Even today, when several schools have been closed and several others re-located in Lomond, Retlaw, and Enchant under a consolidation of schools, 71% of the farms are only three miles or less from a school. Just one farm was more than seven miles from a school. Remoteness from a school was not a major reason for abandonment, although the relatively great distance between neighbors was no doubt a factor in the movement

TABLE 7.—MILES FROM SCHOOL, 126 ABANDONED FARMS, LOMOND AREA OF ALBERTA

Miles	1	2	3	4	5	6	7	Over 7	Total
Number of farms	21	39	30	11	15	5	4	1	126
Percentage	16	31	24	9	12	4	3	1	100
Cumulative percentage	16	47	71	80	92	96	99	100	100

It is frequently maintained that farms more than ten miles from a shipping point are under a serious handicap in economic production. Economic production for the farmer includes hauling. Farms which are devoted chiefly to wheat growing can be successful and still be more distant from a shipping point than in the case of some other types of agriculture. However, three-quarters of the abandoned farms (Table 8) lie within the ten mile limit. The roads are reasonably good throughout the year. Most of these farms are therefore not handicapped by great distance from shipping points.

TABLE 8.—MILES FROM SHIPPING POINT, 126 ABANDONED FARMS, LOMOND AREA OF ALBERTA

Miles	0–2	3–4	5–6	7–8	9–10	11–12	13–14	Over 14	Total
Number of farms	9	28	21	19	16	12	8	13	126
Percentage	7	22	17	15	13	10	6	10	100
Cumulative percentage	7	29	46	61	74	84	90	100	100

Soils.—A greater proportion of abandonment has occurred on the sands (fine sand and fine sandy loam) than on the loams. Thirty per cent of the farms abandoned were on the sands, though they comprise only about 20% of the total area (three townships in a total area of fifteen townships). Forty-three per cent of the farms were on clay loams. These clay loams are quite inferior to those farther west of the area abandoned. The nitrogen content is low, many stones are present, and the subsoil forms an impervious hardpan in the normally dry years. Ten per cent of the farms had a sufficient number of stones to cause serious difficulty in cultivation.

TABLE 9.—PRESENT OWNERSHIP OF LAND, 126 ABANDONED FARMS, LOMOND AREA OF ALBERTA

—	Private	Municipal	Prov. Govt.	C.P.R.	H.B. Co.	Bank	Mtge. Co's	Other Co's	Soldiers Settlement Board	Known	Not known	Total
Number of farms	31	4	45	3	5	2	22	1	2	115	11	126
Percentage	27	3	40	2	4	2	19	1	2	100		
Cumulative percentage	27	30	70	72	76	78	97	98	100	100		

Forty per cent of the abandoned farms now belong to the Provincial Government (Table 9). Individuals own 27%, municipalities 3%, and the remaining 30% belong to private companies. The number of farms reverting to the Provincial Government and the municipalities for taxes has risen steadily with the greatest numbers of reversions occurring within the last five years. The large number of

farms reverting to the Provincial Government rather than to municipalities is because most of the 126 farms of this study lie in improvement districts under the direct control of the Province of Alberta. Most of the land owned by the private companies was once homesteaded and has been taken over for mortgage indebtedness. The decrease from 88% private ownership at the time of settlement to only 27% now is significant of the amount of insolvency prevailing among the ex-operators.

TABLE 10—ANNUAL AND AVERAGE PRECIPITATION LOMOND AREA OF ALBERTA

Year	Medicine Hat[1]	Expanse Coulee[2]	Lethbridge[1]
1921	12.83	13.51	12.77
1922	11.54	12.32	12.34
1923	13.64	15.50	16.40
1924	9.86	9.55	16.00
1925	14.61	11.29	18.76
1926	11.90	10.58	16.23
1927	25.28	23.89	23.85
1928	7.64	6.77	18.08
1929	10.46	9.83	19.71
1930	12.73	12.51	12.34
1931	6.38	7.54	11.42
Total	136.87	133.29	177.90
Average 11 years (1921–1931)	12.4	12.1	16.2
Average 51 years	13.2	Average 33 years	16.0
Average 1929-1934	12.2		16.2

[1] Soil Drifting Control in Prairie Provinces (1935), p. 39.
[2] Meteorological Service of Canada.

Present Condition of Farms.—Forty-five dwellings were left on these farms, only 21 of which were worthy of the name of house. Those which had disappeared, mostly shacks, were largely in use on other farms and in Lomond, Enchant and Retlaw as granaries, sheds and dwellings. Only three windbreaks were present, indicating that almost no attempt had ever been made to make a permanent home on these farms. Fifty-eight had fences, most of which were badly dilapidated. Indications were present that there had been other fences but that they had been moved elsewhere. Only 27 had a water supply, which in general was poor, both as to quality and quantity, and was without doubt an important cause of abandonment.

Reasons for Abandonment.—A great variety of reasons was given for abandonment, with drought and soil drifting accounting for 59%. Poor soil and stony land accounted for 8% of the reasons, and grasshoppers and cutworms 2%. Over two-thirds of the abandonments, therefore, were due to the purely physical nature of the farm and its environment. Of the remaining third, 8% were personal in nature: family difficulties, poor health, and death. Four per cent were due to foreclosures and 4% to inability to pay for the farm, and quit claims were given.

In the decade 1910 to 1920, 16% of the farms were abandoned in spite of the high prices for farm products then prevailing and the fact that the farmers were tilling virgin soil. A number of these were proved up and left before the war. Some of the land filed upon was found to be too poor to warrant proving up and reverted to the Government after a year or two of discouragement. The good crops of 1915 and 1916 checked abandonment temporarily. The drier-than-average years, 1917 to 1922, coupled with the break in farm prices forced a 22% abandonment of the farms in the five-year period 1921 to 1925, most of these occurring in 1921 and 1922.

Precipitation.—The rainfall of Medicine Hat corresponds more closely with that of the Lomond area than that of any other point where records have been kept for a long enough period to make comparisons of dry years in the Lomond area. Dry years in Western Canada run in irregular cycles. Some groups of dry years at Medicine Hat have been: 1885 to 1890, average rainfall 9.7 inches; 1903 to 1910, 9.8 inches; 1917 to 1922, 11.1 inches. The 51 year average rainfall at Medicine Hat is 13.2 inches. The average for the Lomond area can be computed only from the 11 year records (1921–1931) at Expanse Coulee, during which period it was 12.1 inches. Medicine Hat's average for the same period was 12.4 inches.

TABLE 11.—DATES OF ABANDONMENT, 126 ABANDONED FARMS, LOMOND AREA OF ALBERTA

—	1910–1920	1921–1925	1926–1930	1931–1935	Known	Not known	Total
Number of farms	18	23	18	50	109	17	126
Percentage	16	22	16	46	100		
Cumulative percentage	16	38	54	100	100		

Table 11 shows that 46% of the abandonments have occurred within the last five years. The average number of years since abandonment was 7.6. The reason most frequently given for this is that an abnormal period of drought has obtained in the district since 1928. Rainfall records of a satisfactory nature have not been kept in the area. However, at Lethbridge (only 50 miles away) the average rainfall for the years 1929 to 1934, 16.2 inches, was actually slightly higher than the 33 year average of 16.0 inches. At Medicine Hat the corresponding average for 1929 to 1934 was 12.2 inches; the 51 year average, 13.2 inches. Table 10 shows an exceptionally close rainfall correlation between Medicine Hat and Expanse Coulee for the 11 year period 1921 to 1931. Rainfall records kept by two farmers on the fringe of the Lomond area indicate a similar correlation during the years 1932 to 1934. Exceptional drought, therefore, would not appear to be the chief reason for abandonment, but rather the inability to make farming pay in a normally dry climate. As long as wheat was being grown on virgin soil obtained for homestead fees only, under conditions of better than average rainfall and sold at high prices, farmers were in most cases successful. Unfortunately grasshoppers, cutworms, weeds, and the loss of soil fibre in addition to the return of dry and normal years are now major factors in reduced yields.

Significance of Size of Farm

During the settlement period the quarter-section (160 acres) was the predominant size of farm. A few homesteaders acquired an additional quarter-section by preemption. The operators remaining gradually obtained other farms as the unsuccessful moved out. However, the fact that the remaining operators were ultimately unsuccessful may explain why the farms were little larger at the time of abandonment than they were originally.

TABLE 12.—SIZE OF FARMS BY QUARTERS, 126 ABANDONED FARMS, LOMOND AREA OF ALBERTA

No. of quarter-sections	1	2	3	4	Total
Number of farms	68	37	7	14	126
Percentage	54	29	6	11	100
Cumulative percentage	54	83	89	100	100

In an area of scanty rainfall, successful farms are usually larger than those operated in more humid areas. The average size of farm in Alberta in 1931 was 400 acres; the average size of the Lomond abandoned farms was only 273 acres. Fifty-four per cent of the farms when abandoned were only quarter-sections (160 acres). Only 11% were as large as a section (640 acres) and none was greater. It would appear that one of the contributing causes for abandonment was that these farms were not of optimum size.

Present Occupation.—It is interesting to note that 72% of the 126 operators are still farming elsewhere, while only 15% are engaged in occupations other than farming. The remainder are either retired, unemployed, or deceased. The fact that nearly three-quarters of the former operators are farming elsewhere is indicative that under present conditions they are better able to adjust themselves to farming than to any other vocation. It implies also that the soil, climate, and other physical deficiencies of the Lomond area were the real causes of abandonment.

Recurrence of Settlement.—Few if any of the abandoned farms of the Lomond area are in the long run capable of supporting wheat growing as a major enterprise. However, because wheat-growing has been successful in exceptional years, other operators will again be attracted to these farms when a combination of unusually favorable circumstances occurs. Some permanent policy of management of these abandoned lands would seem advisable.

ECONOMIC ASPECTS OF APPLE PRODUCTION IN ROUVILLE COUNTY, QUEBEC

A. Gosselin[1]

The purpose of this article is to present a summary of the results obtained in a study[2] of the financial returns and the cost of producing apples on 30 orchard farms of the Rouville County, the oldest district of the province of Quebec where apple production is the major farm enterprise. This area is located some 35 miles from the City of Montreal and includes the three parishes of St-Hilaire, Rougemont and Abbotsford. The data contained in the first part of this study were collected in a farm survey conducted for six consecutive years and apply to the crop years 1929 to 1934 inclusive, while the data summarized in the second part were collected through an enterprise cost study carried on during the three years 1932, 1933 and 1934 in order to secure more specific information on the cost of producing and marketing apples in that district.

This study coincides with the economic depression experienced since 1929 and shows the trend followed by this type of business during the past six years. While the financial returns of these farms varied somewhat from year to year according to the size of the apple crop and decreased gradually with falling prices, it must be pointed out that the very low financial returns of these farms in 1934 are due more particularly to the heavy loss of apple trees which were killed or injured by the severe winter conditions of 1933–34.

The farms selected for this study are well representative of this type of farming in the district although they vary in size from 15 to 230 acres. The average size of these farms was 70.6 acres, of which 16.7 acres were in bearing orchard, 8.1 acres in non-bearing orchard, and 14.0 acres in other crops. The balance of the acreage was in pasture, wood and rough land. The bearing orchards range in size from 5 to 50 acres.

Financial Returns.—The financial summary of these farms is presented in Table 1. For the six-year period gross receipts averaged $3,138 per farm. Receipts from apple sales averaged $2,718 or 86.6% of total receipts. The highest receipts were

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[2] This study was conducted by the Economics Branch of the Dominion Department of Agriculture in co-operation with the Rural Economic Service of the Quebec Department of Agriculture.

obtained in 1930 and averaged $3,849 per farm. The lowest receipts were secured in 1934 and averaged $1,942 per farm. Total expenses including inventory decrease averaged $2,106 per farm for the six-year period. The item "other expenses" includes all expenses not otherwise listed such as seed, feed, trees, apple containers, marketing expenses, and miscellaneous expenses.

The farm income is the amount remaining from the year's gross receipts after total farm expenses including an allowance for unpaid family labour and depreciation on buildings and equipment have been deducted. It is what is left to cover wages for the operator's labour for the year and interest on the capital invested in the farm. The average farm income for the six-year period was $1,032 reaching the peak in 1930 with $1,412 and the lowest point in 1934 with $701.

The labour income is computed by deducting from the farm income interest on the total farm investment (calculated at 5% in this survey) and represents the return to the operator for his labour and management—in addition he receives food, fuel and housing derived from the farm. For the six-year period the operator's labour income averaged $102. The average value of farm perquisites and use of dwellings was estimated at $441.

TABLE 1.—FINANCIAL SUMMARY OF 30 ORCHARD FARMS IN ROUVILLE COUNTY, QUEBEC, 1929–1934

Crop year	1929–1930	1930–1931	1931–1932	1932–1933	1933–1934	1934–1935	Six-year average 1929–1934
	$	$	$	$	$	$	$
Capital							
Land	11,348	11,348	11,348	11,690	11,690	11,690	11,519
Buildings	5,323	5,170	5,030	4,940	4,797	4,675	4,989
Machinery	1,607	1,510	1,429	1,484	1,402	1,282	1,453
Live stock	668	634	541	452	426	418	523
Feed and supplies	71	94	130	122	124	100	107
Total Capital	19,017	18,756	18,478	18,688	18,439	18,165	18,591
Receipts							
Apples	2,899	3,282	3,053	2,995	2,394	1,685	2,718
Other crops	165	123	44	59	39	42	79
Livestock sales	161	94	52	35	14	47	67
Livestock products	187	135	101	72	75	72	107
Other receipts	211	115	116	24	50	67	97
Inventory increase	79	100	92	90	29	29	70
Total Receipts	3,702	3,849	3,458	3,275	2,601	1,942	3,138
Expenses							
Unpaid labour	318	387	304	136	153	117	236
Hired labour	600	561	501	560	507	411	523
Spray material	69	82	85	117	112	90	92
Fertilizer	115	158	141	104	68	84	112
Taxes	110	99	98	102	93	95	99
Capital expenditures	85	153	104	97	43	41	87
Other expenses	726	635	541	914	547	400	627
Inventory decrease	309	362	384	317	294	312	330
Total Expenses	2,332	2,437	2,158	2,347	1,817	1,550	2,106
Farm income	1,370	1,412	1,300	928	784	392	1,032
Interest at 5 per cent	951	938	924	936	923	910	930
Labour income	419	474	376	−8	−139	−518	102

Cash Income.—The cash income often amounts to considerably more than the farm income computed in the usual way, because all non-cash expenses such as depreciation, decrease in inventory, unpaid family labour are not deducted from cash receipts. The remaining amount represents the actual cash the farmer has left to use for family living, for the payment of interest on borrowed capital and for making equipment replacement, and for building and farm improvements as needed. This is the measure of efficiency commonly used by the farmer, but since all farmers are not placed on the same basis in regard to unpaid family labour, it makes comparisons among individual farms somewhat difficult. It explains, however, how farmers can carry on through such a depression without being bankrupt. The cash income of these farmers averaged $1,528 for the six-year period and the estimated value of the products supplied by the farm amounted to $170, while the rental value of the house they live in was estimated at $271 making a total amount of $1,969 for what might be called total family income.

TABLE 2.—CASH INCOME OF 30 ORCHARD FARMS IN ROUVILLE COUNTY, QUEBEC, 1929–1934

—	1929	1930	1931	1932	1933	1934	Six-year average
	$	$	$	$	$	$	$
Cash Receipts							
Apples	2,899	3,282	3,053	2,995	2,394	1,685	2,718
Other receipts	724	467	313	190	178	228	350
Total	3,623	3,749	3,366	3,185	2,572	1,913	3,068
Cash Expenses							
Hired labour	600	561	501	550	507	411	523
Spray material	69	82	85	117	112	90	92
Fertilizer	115	158	141	104	68	84	112
Taxes	110	99	98	102	93	95	99
Capital expenditures	85	153	104	97	43	41	87
Other expenses	726	635	541	914	547	400	627
Total	1,705	1,688	1,470	1,884	1,370	1,121	1,540
Cash income	1,918	2,061	1,896	1,301	1,202	792	1,528

Cost of Producing Apples.—The accurate determination of the cost of production of apples, as of any farm product which is produced in combination with other farm enterprises, is very difficult. There are numerous joint costs which have to be allocated by somewhat arbitrary methods; for instance, man and horse labour, use of machinery and buildings, overhead costs, etc. Man labour is one of the most important single items of cost of producing apples and also the most difficult to allocate. The orchard business provides work for about eight months of the year and the operator has to stay on the farm the whole year whether he has some work to do or not. It is obvious that on a small orchard of between five and ten acres the operator's labour estimated at what it would cost to hire a man for the year to take his place makes the labour charge per hour of productive work much higher than the current rate for hired labour. Nevertheless the orchard business being the major farm enterprise must bear the largest share of this charge.

The same thing applies to horse labour. On most orchard farms two horses are required for spraying, mowing the orchard, and hauling apples. They remain idle for the greater part of the rest of the time, and it costs about as much to keep them as if they work every day.

The cost of producing apples is presented in Table 3. The average size of bearing orchard per farm for the three years 1932-1934 was 17.4 acres with an average of 64.6 bearing trees to the acre. The average investment per farm in land and trees was

TABLE 3.—COST OF PRODUCING APPLES PER ACRE AND PER BARREL ON 30 ORCHARD FARMS IN ROUVILLE COUNTY, QUEBEC, 1932–1934

Item	1932	1933	1934	3-year average
	$	$	$	$
Overhead Costs				
Taxes	4.80	4.67	4.67	4.72
Repairs to buildings and equipment	1.42	1.13	1.09	1.21
Miscellaneous	2.04	1.88	1.84	1.92
Total overhead costs	8.26	7.68	7.60	7.85
Growing Costs				
Man labour	16.17	15.73	15.65	15.85
Horse labour	4.52	4.41	4.04	4.32
Spray material	6.21	5.91	4.68	5.60
Fertilizer	3.37	2.93	3.58	3.29
Manure and straw	3.38	3.14	2.14	2.89
Total growing costs	33.65	32.12	30.09	31.95
Harvesting Costs				
Man labour	17.09	14.94	8.33	13.45
Horse labour	1.35	1.22	0.80	1.12
Total harvesting costs	18.44	16.16	9.13	14.57
Total cost exclusive of depreciation and interest	60.35	55.96	46.82	54.37
Depreciation charge on building and equipment	5.28	4.94	4.75	4.99
Interest charge on investment at 5 per cent	30.32	29.37	29.24	29.64
Total cost of production per acre	95.95	90.27	80.81	89.00
Yield per acre (barrels)	81.6	67.9	32.6	60.7
Cost per barrel	1.18	1.33	2.48	1.47

$9,040 or $519 per acre of bearing orchard and $8 per bearing tree; the investment in buildings (fruit house only) was $716 per farm or $41.11 per acre; the investment in orchard equipment was $582 per farm or $33.45 per acre. In addition to that there was an average of 8.0 acres of non-bearing orchard.

The overhead and growing costs per acre vary little from year to year unless something quite unusual occurs. In 1934 the growing costs per acre were somewhat lower than in 1932 and 1933 because of the large number of bearing trees killed during the previous winter.

Harvesting costs are closely related to the size of apple crop. A larger yield means more labour for picking and handling the crop. However, since the harvesting costs constitute only a certain percentage of the total cost of production per acre, a big crop of apples is usually produced at a much lower cost per barrel than a small crop.

The interest charge on orchard investment is an important item of cost. It amounted to 33.3% or exactly one-third of the total average cost of production per acre for the three years.

The crop of 1932 was a good one. The yield averaged 81.6 barrels per acre on these 30 farms and the cost of production $1.18 per barrel. The average yield of 67.9 barrels per acre in 1933 was a little higher than the average yield of 62.0 barrels per acre for the six years 1929–1934 and the cost of production per barrel averaged $1.33. The crop of 1934 was a failure resulting from the heavy loss of bearing trees during the previous winter; the average yield per acre was only 32.6 barrels and the average cost of production $2.48 per barrel. This accounts for the relatively high average cost of producing apples of $1.47 per barrel for the three years 1932–1934.

TABLE 4.—RANGE IN COST OF PRODUCTION PER BARREL ON 30 ORCHARD FARMS IN ROUVILLE COUNTY, QUEBEC, 1932–1934

Range	Number of farms	Barrels produced	Range in cost per barrel	Average cost per barrel
$			$	$
Under 1.50	12	59,293	0.92–1.47	1.17
1.50–2.00	8	22,034	1.52–1.98	1.70
2.00–2.50	5	9,120	2.07–2.41	2.11
Over 2.50	5	4,577	2.57–3.27	2.82
Average	30	95,204	0.92–3.27	1.47

Range in Cost of Producing Apples.—The total cost of producing apples per barrel including the depreciation and interest charges varies widely from farm to farm and from year to year according mainly to the yield secured. Crop failures due to hail, wind storms and particularly the disastrous winter season of 1934 explain the abnormally high cost on a few farms for the three years 1932–1934. While the average cost of production per barrel was $1.47 for this period it ranged from $0.92 to $3.27 on individual farms.

SURVEY OF THE MARKETING OF FRUITS AND VEGETABLES IN THE CITY OF TORONTO AND THE SURROUNDING DISTRICT

At the request of the Toronto Terminal Market Committee, which is composed of representatives of fruit and vegetable growers, wholesalers, jobbers and commission merchants, the city of Toronto, retail store keepers, railroad and steamship lines and the Ontario and Dominion Governments under the chairmanship of Mr. Paul Fisher, appointed by the Ontario Minister of Agriculture, a comprehensive survey has been undertaken by the Economics Branch in co-operation with the Fruit Branch of the Dominion Department of Agriculture and the Ontario Department of Agriculture, to obtain information with respect to the marketing and distribution of fruits and vegetables in and about the city of Toronto. Data will be gathered on the volume and value of fruits and vegetables of all kinds consumed in Toronto, the source of such produce, the quantity transported to the city by railroads, trucks and boats, the volume handled by Toronto wholesalers and jobbers, the volume handled through public markets by growers and truckers, the quantities purchased direct by retailers at the store door from growers and truckers, and many other related facts which are deemed essential to the work of the Committee.

In addition to the survey outlined, the work of the Committee will include a consideration of various locations for a new terminal market in Toronto, the various methods of financing such a project, and the regulations and by-laws which should be passed if a market is established.

The gathering of the necessary facts and the tabulation of the figures obtained will cover a period of several months.

The Extension Division, St. Francis Xavier University, has organized Adult Study Clubs throughout Eastern Nova Scotia, and these have been utilized as a means of getting the people of the county to take an intelligent interest in their problems. Lessons prepared by the Nova Scotia Department of Agriculture, using the Antigonish County Survey Report as the chief reference. Each lesson presents a few facts concerning the subject to be studied, references, topics for discussion and questions designed to cause the student to apply these facts to his own farm or locality. Mr. S. J. MacKinnon, Agricultural Representative, reports a keen interest and an especially good group of meetings during the winter.